DOCUMENT RESUME

ED 267 250 CE 043 813

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TITLE Mathematics for Electronics.

INSTITUTION North Carolina State Univ., Raleigh. Dept. of Occupational Education.
SPONS AGENCY North Carolina State Dept. of Public Instruction, Raleigh. Div. of Vocational Education.
PUB DATE 85
NOTE 139p.; Document contains colored paper.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC06 Plus Postage.
DESCRIPTORS Behavioral Objectives; Competence; Competency Based Education; Educational Needs; *Electricity; *Electronics; High Schools; Learning Modules; *Mathematical Applications; *Mathematical Concepts; *Mathematics Instruction; Metric System; Problem Sets; Vocational Education
IDENTIFIERS North Carolina

ABSTRACT

This set of 20 modules was designed for use primarily to help teach and reinforce the basic mathematics skills in electronics classes. The modules are based on electronics competencies that require mathematics skills, as determined by a panel of high school electronics and mathematics teachers. Each module consists of one or two pages of basic information, including a brief discussion of the electronics concepts involved, formulas, and examples showing how the formulas are used. Following the information sheet(s) are several sheets of problems for the students to work; solutions are included. Also included with the modules is a "teach sheet" of basic mathematics rules, and a module on metrics. Topics covered by the modules are the following: mathematics rules, broadcast frequency, calculating cost of power, calculating power, circuit value, decibels, frequency, horsepower, impedance, instantaneous sine voltage, metrics, Ohm's Law, Op-amplifiers, reactance, rectification, resistance (parallel), resistance (series), transformer ratios, voltage, and wavelength. (KC)

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MATHEMATICS FOR ELECTRONICS

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1985

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CE043813

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Special thanks to the following teachers for their help in the development of these modules:

Bill Ellis, Electronics Teacher, N. Johnston High School, Kenly, N. C.

Mary Belle Pate, Mathematics Teacher, Millbrook High School, Raleigh, N. C.

Thor Puckett, Electronics Teacher, Millbrook High School, Raleigh, N. C.

Jane Sullivan, Mathematics Teacher, Garner Sr. High School, Garner, N. C.

and to

Chris Mullen, Student, Sanderson High School, Raleigh, N. C. for artwork

Julie Capps, Graduate Assistant, NCSU, Raleigh, N. C. for typing

Funded under a contract through the Research Coordinating Unit, Division of Vocational Education, Department of Public Instruction, under the auspices of federal law 94-482, FY 1985.

Activities and procedures funded by the Division of Vocational Education are governed by the philosophy of simple fairness to all. Therefore, the policy of the Division is that all operations will be performed without regard to race, sex, color, national origin, or handicap.

To teachers:

This set of modules was designed for use primarily by electronics teachers to help them teach and reinforce the basic math skills in their electronics classes. The modules are based on electronics competencies which a panel of high school electronics and mathematics teachers determined to require math skills. It is also hoped that mathematics teachers will find the modules useful in reviewing math skills and helping students realize the need for math in the working world.

Each module consists of 1-2 pages of basic information (yellow sheets) including a brief discussion of the electronics concepts involved, formulas, and examples showing how the formulas are used. Following the information sheet(s) are several sheets of problems (green sheets) for the students to work. On the back of each sheet of problems are the solutions.

The modules have been hole punched to fit in a 3 ring binder so they will be easily accessible. Modules may be given to students as a complete assignment or broken down into smaller parts according to the needs of the students.

Also included with the modules is a "Teach Sheet" of basic math rules. It may be helpful to provide a copy of these sheets to each student. A module on metrics is also included. A number of the modules require an understanding of the metric system. It may be helpful to provide a copy of the metric information sheet (yellow) to students who have problems.

A set of electronics competencies which a panel of electronics and mathematics teachers determined to require mathematics skills is included. This set of competencies was verified through a survey of North Carolina secondary electronics teachers. The set of competencies was used as the basis for developing this set of modules. Each module is based on one of the electronics competencies.

ELECTRONICS COMPETENCIES

010.06 MEASURE VOLTAGE DROPS IN SERIES CIRCUITS.

011.03 CONVERT AMPERES TO MILLIAMPERES AND MICROAMPERES.

012.00 USE OHM'S LAW TO FIND:
- AN UNKNOWN VOLTAGE.
- AN UNKNOWN CURRENT.
- AN UNKNOWN RESISTANCE.
- AN UNKNOWN POWER.

015.02, 016.03, 017.05 USE FORMULAS FOR SERIES CIRCUITS, PARALLEL AND SERIES-PARALLEL CIRCUITS.

019.04 CALCULATE MOTOR HORSEPOWER.

020.04 LIST FORMULAS , COMPUTE PERIOD, WAVE LENGTH, AND INSTANTANEOUS SINE VOLTAGE VALUES OF AC.

022.01 ...ABILITY TO COMPUTE TRANSFORMER RATIOS.

023.03 COMPUTE APPLIED VOLTAGE AND IMPEDANCE OF SERIES RL CIRCUIT, INDUCTIVE REACTANCE, USE AND LABEL A UNIVERSAL TIME CONSTANT CHART AND LIST FACTORS NEEDED FOR COMPUTING INDUCTIVE REACTANCE.

028.02 COMPUTE VALUES ASSOCIATED WITH RC, RL AND RCL CIRCUITS.

031.03 COMPUTE AC INPUT OR DC OUTPUT USING FORMULAS ASSOCIATED WITH RECTIFIER CIRCUITS.

035.09 COMPUTE VOLTAGE, CURRENT, AND POWER GAINS IN EACH UNIT AND IN DB OF SINGLE AND MULTISTAGE AMPLIFIERS.

036.08, 036.10, 037.06 CALCULATE THE GAIN FOR AN INVERTING AND NONINVERTING OP-AMPLIFIER AND THE OUTPUT VOLTAGE OF A DC SUMMING AND DIFFERENTIAL OP-AMPLIFIERS.

038.02 ...COMPLETE TRUTH TABLES FOR HALF-ADDERS, AND, OR, NAND, NOR, XOR GATES AND INVERTOR (NOT) GATES.

043.05 COMPUTE THE OUTPUT FREQUENCIES OF A STANDARD AM MIXER STAGE GIVEN THE FREQUENCY OF THE RF SIGNAL AND THE LOCAL OSCILLATOR FREQUENCY.

MATH COMPETENCIES

1. THE LEARNER WILL DEMONSTRATE AN UNDERSTANDING OF THE BASE TEN NUMBER SYSTEM.

2. THE LEARNER WILL PERFORM OPERATIONS WITH WHOLE NUMBERS.

3. THE LEARNER WILL PERFORM OPERATIONS WITH FRACTIONAL NUMBERS.

4. THE LEARNER WILL PERFORM OPERATIONS WITH DECIMAL NUMBERS.

5. THE LEARNER WILL PERFORM OPERATIONS WITH PERCENT.

6. THE LEARNER WILL USE THE STRUCTURAL PROPERTIES OF NUMBER SYSTEMS.

7. THE LEARNER WILL BE ABLE TO USE THE ORDER OF OPERATIONS TO EVALUATE EXPRESSIONS.

8. THE LEARNER WILL SOLVE LINEAR EQUATIONS.

9. THE LEARNER WILL BE ABLE TO SIMPLIFY EXPRESSIONS USING LAWS OF EXPONENTS.

10. THE LEARNER WILL PERFORM OPERATIONS WITH ALGEBRAIC FRACTIONS.

11. THE LEARNER WILL BE ABLE TO USE A SCIENTIFIC CALCULATOR.

12. THE LEARNER WILL DEMONSTRATE AN UNDERSTANDING OF NUMBER SYSTEMS OTHER THAN BASE TEN.

13. THE LEARNER WILL DEMONSTRATE AN UNDERSTANDING OF METRIC MEASURE.

14. THE LEARNER WILL BE ABLE TO SELECT THE APPROPRIATE FORMULAS TO SOLVE SPECIFIC PROBLEMS AND TRANSFORM THOSE FORMULAS WHEN NECESSARY.

15. THE LEARNER WILL BE ABLE TO EXPRESS WORD PHRASES AS NUMERICAL EXPRESSIONS.

16. THE LEARNER WILL BE ABLE TO INTERPRET INFORMATION DISPLAYED IN GRAPHICAL FORM.

References

Fowler, R. J. (1979). Electricity principles and applications. New York: McGraw-Hill Book Company.

Robertson, L. P. (1982). Basic electronics I. Mid-America Vocational Consortium, Inc.

Singer, B. B. (1965) . Basic mathematics for electricity and electronics. New York: McGraw-Hill.

Willison, N. A., & Shelton, J. K. (1981). Electronics II. Mid-America Vocational Consortium, Inc.

MODULES

Teach sheet

Broadcast Frequency

Calculating Cost of Power

Calculating Power

Circuit Value

Decibels

Frequency

Horsepower

Impedance

Instantaneous Sine Voltage

Metrics

Ohm's Law

Op-amplifiers

Reactance

Rectification

Resistance (parallel)

Resistance (series)

Transformer Ratios

Voltage

Wavelength

TEACH SHEET

MATH RULES TO USE WITH FORMULAS

I. USING ORDER OF OPERATIONS

After substituting values in a formula, remember the rules:

* Simplify expressions inside parentheses
* Clear exponents
* Multiply and divide from left to right
* Add and subtract from left to right
* Remember fraction bars or radical signs are grouping symbols. Complete operations above and below fraction bar or inside radical before completing problem.

Examples:

$5^2 + (25 - 20)^2 =$

$5^2 + 5^2 =$

$25 + 25 =$

50

$$\frac{1}{(4\pi)^2 \times 5^2 \times 2^2} =$$

$$\frac{1}{(12.56)^2 \times 5^2 \times 2^2} =$$

$$\frac{1}{157.75 \times 25 \times 4} =$$

$$\frac{1}{3943.75 \times 4} =$$

$$\frac{1}{15775} =$$

.00006

II. USING FRACTIONS

* Get lowest common denominator (LCD) for addition and subtraction

Example:

$$\frac{1}{\frac{1}{10} + \frac{1}{5} + \frac{1}{20} + \frac{1}{15}} =$$

$$\frac{1}{\frac{6}{60} + \frac{12}{60} + \frac{3}{60} + \frac{4}{60}} =$$

$$\frac{1}{\frac{25}{60}} =$$

$$\frac{60}{25} =$$

$$\frac{12}{5}$$

III. USING PERCENT

* When multiplying with percent, change to decimal first by moving decimal two places to the left.

Example:

30.2% = .302

5.1% = .051

10% = .10

5% of 100 = .05 x 100

IV. USING LAWS OF EXPONENTS

* When multiplying like bases, add exponents
* When dividing, subtract exponents

Examples:

$$\frac{3 \times 10^6}{10 \times 10^4} =$$

$$\frac{3}{10} \times \frac{10^6}{10^4} =$$

$$.3 \times 10^{6-4} =$$

$$.3 \times 10^2 =$$

$$30$$

V. USING RATIOS AND PROPORTIONS

* $a : b = c : d$ means $\frac{a}{b} = \frac{c}{d}$ which solves by $a \times d = c \times b$

Example:

To solve for d when a, b, and c, are known.

$2 : 4 = 6 : d$ means $\frac{2}{4} = \frac{6}{d}$ Solve for d:

$$2 \times d = 6 \times 4$$

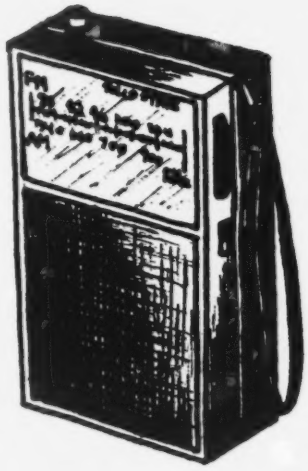
$$2 \times d = 24$$

$$\frac{2 \times d}{2} = \frac{24}{2}$$

$$d = 12$$

BROADCAST FREQUENCY

Most of us have an AM radio in our home or car. We tune the dial to our favorite station and think little about why the station broadcasts at the frequency it does.



Each station transmits at a given frequency. The receiver is tuned to this frequency, and at the same time, the local oscillator is tuned to a specific frequency. The intermediate frequency (If) is determined by using the received station frequency (Rf) and the oscillator frequency (Of) in the following formula:

$$If = Of - Rf$$

Frequencies are measured in Hertz (Hz) or KiloHertz (KHz).

Example:

Find the intermediate frequency if the oscillator frequency is 75 KHz and the station frequency is 50 KHz.

$$If = Of - Rf$$

$$If = 75 - 50$$

$$If = 25 \text{ KHz}$$

Problems

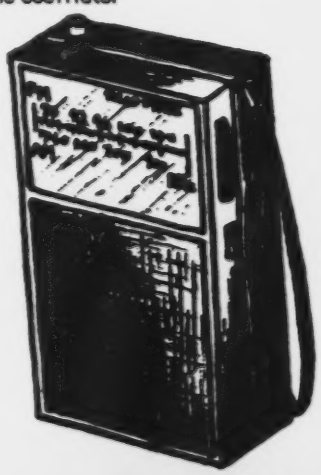
Following are some problems that will help you better understand how broadcast frequencies are determined.

1. The station frequency is 565 KHz, and the oscillator frequency is 1020 KHz. What is the If frequency Cynthia's radio uses?

2. The If stage operates on 70.7 KHz. The station is transmitting 89 KHz. What is the oscillator frequency?

3. The If frequency is 32 KHz, and the oscillator frequency is 250 KHz. What is the station frequency?

4. Jeffery knows that the frequency of his favorite station is 450 KHz and that the oscillator frequency is 900 KHz. What is the intermediate frequency?



SOLUTIONS

1. $If = Of - Rf$

   $If = 1020 - 565$

   $If = 455$ KHz

2. $Of = If + Rf$

   $Of = 70.7 + 89$

   $Of = 159.7$ KHz

3. $Rf = Of - If$

   $Rf = 250 - 32$

   $Rf = 218$ KHz

4. $If = Of - Rf$

   $If = 900 - 450$

   $If = 450$ KHz

5. You know the oscillator frequency is 200 KHz, and the received station frequency is $\frac{1}{2}$ the oscillator frequency.

   a. What is the received station frequency?

   b. What is the intermediate frequency?

6. You know the intermediate frequency is 500 KHz and the received radio frequency is $\frac{1}{5}$ of the intermediate frequency.

   a. What is the received radio frequency?

   b. What is the oscillator frequency?

7. The received station frequency is 200 and the oscillator frequency is twice as large as the received station frequency.

   a. What is the oscillator frequency?

   b. What is the intermediate frequency?

5. $Of = 200$ KHz

a. $Rf = \frac{200}{2}$

$Rf = 100$ KHz

b. $If = Of - Rf$

$If = 200 - 100$

$If = 100$ KHz

6. $If = 500$ KHz

a. $Rf = \frac{500}{5}$

$Rf = 100$ KHz

b. $If = Of - Rf$

$500 = Of - 100$

$Of = 500 + 100$

$Of = 600$ KHz

7. $Rf = 200$ KHz

a. $Of = 2 \times 200$ KHz

$Of = 400$ KHz

b. $If = 400 - 200$

$If = 200$ KHz

Calculating Cost of

POWER

Every device (load) we use in electronics develops power (P) as voltage pushes current through the device. We pay for the use of voltage by how much power we use. The total power (P_T) used in any circuit is always equal to the sum of power (P) developed by each device, P_{R_1}, P_{R_2}, P_{R_3}, etc.

The formula for total power in a circuit is:

$$P_T = P_{R_1} + P_{R_2} + P_{R_3} + \text{etc.}$$

Power is measured in watts. We pay for power according to how many kilowatt hours we use.

1 Kilowatt (KW) = 1000 watts

(to determine how many KW are used, divide Pr by 1000W)

Kilowatt hour (KWH) = KW x hours

The cost of power can be determined by using the formula:

Cost = KWH used x cost per KWH

Examples:

A circuit has two lights and a radio. The lights each require 60 watts and the radio requires 150 watts. What is the total power used?

$P_T = P_{R1} + P_{R2} + P_{R3}$

$= 60 + 60 + 150$

$= 270$ watts

How many kilowatt hours would be used in 2 hours?

1 KW = 1000 watts

$\frac{270}{1000} = .27$ KW

KWH = KW x hours

$= .27 \times 2$

$= .54$ KWH

How much would it cost at a rate of $.08 per KWH?

Cost = KWH used x Cost per KWH

Cost = .54 x .08

Cost = $ .04

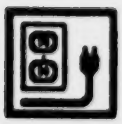
PROBLEMS

Using the information given above, work the following problems.

1. What is the cost of 400 KWH of energy when the rate is $ .05 per KWH?

2. Julie used her study lamp for 3 hours with a 150 watt bulb in it. How much did it cost her to use it that long if electricity costs $ .035 per KWH?

3. Paul Johnson has an electric hot water heater in his house. It has a 3200 watt heating element. The heater is on for 7 hours one day. How much did it cost for that day if the rate is $.04 per KWH?



SOLUTIONS

1. Cost = KWH used x Cost per KWH

   Cost = 400 x $.05

   Cost = $20.00

2. 1 KW = 1000 Watts

   $\frac{150}{1000}$

   .15 KW = 150 Watts

   KWH = KW x Hours

   KWH = .15 x 3

   KWH = .45

   Cost = KWH used x Cost per KWH

   Cost = .45 x $.035

   Cost = $.015

3. 1 KW = 1000 W

   $\frac{3200}{1000}$

   3.2 KW = 3200W

   KWH = KW x Hours

   KWH = 3.2 x 7

   KWH = 22.4

   Cost = KWH used x Cost per KWH

   Cost = 22.4 x $.04

   Cost = $.896

Sally Salamander has a fan that needs 40 watts, a hair dryer that needs 1200 watts, and a curling iron that needs 600 watts.

4. What is the total power Sally's appliances require?

5. How many Kilowatts of power would Sally's appliances utilize?

6. Assume that Sally operates all the appliances at the same time. How many kilowatt hours are consumed in 30 minutes? 1 hour?

7. Sally pays $ .08 per KWH.

   a. How much does it cost to use the three appliances simultaneously for 30 minutes?

   b. 1 hour?

4. $P_T = P_{R_1} + P_{R_2} + P_{R_3}$

$P_T = 40 + 1200 + 600$

$P_T = 1840$ watts

5. 1840 watts = 1.84 KW

$\frac{1840}{1000} = 1.84$ KW

6. KWH = KW x hour

1.84 x .5 = .92 KWH

1.84 x 1 = 1.84 KWH

7. a. .92 KWH x $ .08 = $ .0736

b. 1.84 KWH x $ .08 = $ .1472

Ronny Roadrunner has an electric razor that uses 30 watts, an electric heater that requires 2400 watts and a radio that needs 500 watts. Suppose Ronny uses each of these appliances simultaneously every morning in January for 10 minutes.

8. What is the total power Ronny's appliances require?

9. a. How many kilowatts of power would the appliances use?

   b. How many KWH's would Ronny use in one day?

10. Ronny pays $ .08 per KWH of power he uses.

    a. How much would it cost him to operate the appliances for one day?

    b. one week?

    c. the month of January (31 days)?

8. $P_T = P_{R_1} + P_{R_2} + P_{R_3}$

$P_T = 30 + 2400 + 50$

$P_T = 2930$ watts

9. a. 2930 watts = 2.93 KW

$\frac{2930}{1000} = 2.93$ KW

b. 10 minutes = .16 hours $(\frac{10}{60})$

$2.93 \times .16 = .4688$kw

10. a. $.4688 \times .08 = \$ .038$

b. $\$ .038 \times 1 = \$ .26$

c. $\$ .038 \times 31 = \$ 1.178$

CALCULATING POWER

Power (P) = Current (I) X Voltage (V)

Or: P = IV

Current and voltage are easy to measure. Power is equal to current times voltage. The relationship between these three (power, current, and voltage) will be used quite often in electronics.

Power will be expressed in watts (w), voltage in volts (v), and current in amperes (a). Let's use the formula to work a few problems. Try working them on your own. Then check your work by looking on the back side of the sheet to find the solutions and correct answers.

Examples:

Given:	Given:	Given:
Current (I) = 4 amps	Power = 480 watts	Power = 240 watts
Voltage (V) = 120 volts	Voltage = 120 volts	Current = 2 amps
Power (P) = ?	Current = ?	Voltage = ?
P = IV	P = IV	P = IV
P = 4 x 120	480 = I x 120	36 = 10 x V
P = 480 watts	$\frac{480}{120} = I$	$\frac{240}{2} = V$
	I = 4 amps	V = 120 volts

Problems

Work the following problems using the formula for calculating power.

1. An electric heater is plugged into a 120 volt outlet. It draws 7 amperes. What is the power input to the heater?

2. Mary Smith has an electric iron which draws 8 amperes of current from a 120 volt outlet. What is its power input?

3. Billy Budd uses a 250 watt lamp to light his study area. When he plugs it into a 120 volt outlet, how much current does it draw?

Solutions

1. Given: Current (I) = 7 amperes (A)

   Voltage (V) = 120 volts (V)

   Find: Power (P)

   Formula: P = IV

   Solution: P = 7 A x 120 V = 840 watts (W)

   Answer: Power input to the electric heater is 840 W.

2. Given: Current (I) = 8 amperes (A)

   Voltage (V) = 120 volts (V)

   Find: Power (P)

   Formula: P = IV

   Solution: P = 8 A x 120 V = 960 watts (W)

   Answer: The power input to the electric iron is 960 W.

3. Given: Voltage (V) = 120 volts (V)

   Power = 250 watts (W)

   Find: Current (I)

   Formula: $I = \frac{P}{V}$

   Solution: $I = \frac{250\ W}{120\ V} = 2.0833\ A$

   Answer: = The current drawn by the lamp is 2.0833 amperes.

4. Jane Moore fixes toast each morning in a 1000 watt toaster. It operates from a 120 volt outlet. How much current is required to operate the toaster?

5. Sandy Rhodes dries her clothes in cold weather in an electric clothes dryer. The heating element is rated as 4 kilowatts (kW) and 240 volts (V). How much current does it draw?

6. An electric fan has a power input of 360 watts and draws 3 amps of current. What is the voltage in the outlet it is plugged into?

4. Given: Voltage (V) = 120 volts (V)

Power (P) = 1000 watts (W)

Find: Current (I)

Formula: $I = \frac{P}{V}$

Solution: $I = \frac{1000}{120} = 8.333\ A$

Answer: The current required to operate the toaster is 8.333 amperes.

5. Given: Voltage (V) = 240 volts (V)

Power (P) = 4000 watts (W)

Find: Current (I)

Formula: $I = \frac{P}{V}$

Solution: $I = \frac{4000}{240} = 16.667\ A$

Answer: The amount of current drawn by the electric dryer is 16.667 amperes.

6. Given: Power (P) = 360 watts (W)

Current (I) = 3 amps

Find: Voltage (V)

Formula: $V = \frac{P}{I}$

Solution: $\frac{360}{3} = 120\ V$

Answer: The amount of voltage in the outlet is 120 volts.

CIRCUIT VALUE

When capacitance (C), inductance (L), and resistance (R) are used in a circuit with alternating current, the frequency (f) has a definite effect on the parameters of almost all values in the circuit. The following formulas can be used to determine the various values in the circuit:

$$L = \frac{1}{4(\pi)^2 f^2 C} \qquad C = \frac{1}{4(\pi)^2 f^2 L}$$

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Where:

L = inductance [measured in Henries (h)]

C = capacitance [measured in Farads (F)]

f = frequency [measured in Hertz (Hz)]

X_L = inductive reactance (measured in ohms Ω)

Z = impedance (measured in ohms Ω)

X_C = capacitive reactance (measured in ohms Ω)

R = resistance (measured in ohms Ω)

Examples:

Given: f = 60 Hz
L = .003 h

Find: Capacitance

$$C = \frac{1}{4(\pi)^2 f^2 L}$$

$$C = \frac{1}{4(\pi)^2 (60)^2 (.003)}$$

$$C = \frac{1}{(39.48)(3600)(.003)}$$

$$C = \frac{1}{426.38}$$

$$C = .0023 \text{ F}$$

Given: f = 250 Hz
C = .000002 F

Find: Inductance

$$L = \frac{1}{4(\pi)^2 f^2 C}$$

$$L = \frac{1}{4(\pi)^2 (250)^2 (.000002)}$$

$$L = \frac{1}{(39.48)(62500)(.000002)}$$

$$L = \frac{1}{4.935}$$

$$L = .2026 \text{ h}$$

Given: L = .50 h
C = .05 F

Find: Frequency

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{(.50)(.05)}}$$

$$f = \frac{1}{6.28\sqrt{.025}}$$

$$f = \frac{1}{(6.28)(.158)}$$

$$f = \frac{1}{.992}$$

$$f = 1.008 \text{ Hz}$$

Given: X_L = 6 ohms
X_C = 30 ohms
R = 300 ohms

Find: Impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{(300)^2 + (6 - 30)^2}$$

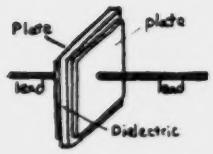
$$Z = \sqrt{90000 + (-24)^2}$$

$$Z = \sqrt{90000 + 576}$$

$$Z = \sqrt{90576}$$

$$Z = 300.96 \text{ ohms}$$

PROBLEMS



Capacitor

Using the formulas given, work the following problems to find the missing value.

1. When Sam's capacitor burned up, he needed to know what value to replace it with. He found the frequency was 90 Hz and the inductance was .004 h. What value capacitor should he use?

2. Sam had a circuit with a frequency of 500 Hz and a capacitance of .000005 farads. How much inductance was in the circuit?

3. George has a circuit with a coil value (inductance) of .025 henries and a capacitor of .0005 farad. At what frequency will this circuit operate best?

4. If George's circuit has 10 ohms of capacitive reactance, 50 ohms inductive reactance, and 500 ohms of resistance, what is the impedance?

SOLUTIONS

1. $C = \frac{1}{4(\pi)^2(90)^2(.004)}$

$C = \frac{1}{(39.48)(8100)(.004)}$

$C = \frac{1}{(39.48)(8100)(.004)}$

$C = \frac{1}{1279.15}$

$C = .00078\ f$

2. $L = \frac{1}{4(\pi)^2 f^2 C}$

$L = \frac{1}{(39.48)(500)^2(.000005)}$

$L = \frac{1}{(39.48)(250000)(.000005)}$

$L = \frac{1}{49.35}$

$L = .02026\ h$

3. $f = \frac{1}{2\pi\sqrt{LC}}$

$f = \frac{1}{2\pi\sqrt{(.025)(.0005)}}$

$f = \frac{1}{6.283\sqrt{.0000125}}$

$f = \frac{1}{(6.283)(.00353553)}$

$f = \frac{1}{.0222137}$

$f = 45.0173\ Hz$

4. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{500^2 + (50 - 10)^2}$

$Z = \sqrt{500^2 + 40^2}$

$Z = \sqrt{250000 + 1600}$

$Z = \sqrt{251600}$

$Z = 501.5974\ \Omega$

5. Wayne knows the frequency in his circuit is 95 Hz and the inductance is .04 h. What is the capacitance?

6. Woodley wants to know what the inductance is in his circuit if the frequency is 700 Hz and the capacitance is .00006 F. What is the inductance?

7. Warren knows the inductance in a circuit is .725 h and the capacitance is .0043 F. What is the frequency?

8. Jean knows her circuit has 25 ohms of inductive reactance, 47 ohms of capacitive reactance and 1543 ohms of resistance. What is the impedance?

5. $C = \frac{1}{4(\pi)^2 f^2 L}$

$C = \frac{1}{4(\pi)^2 (95)^2 (.04)}$

$C = \frac{1}{(39.48)(9025)(.04)}$

$C = \frac{1}{14{,}252.28}$

$C = .0000702\ F$

6. $L = \frac{1}{4(\pi)^2 (f^2) C}$

$L = \frac{1}{4(\pi)^2 (700)^2 (.00006)}$

$L = \frac{1}{(39.48)(490000)(.00006)}$

$L = \frac{1}{1160.172}$

$L = .0008615\ h$

7. $f = \frac{1}{2\pi \sqrt{LC}}$

$f = \frac{1}{2\pi \sqrt{(.725)(.0043)}}$

$f = \frac{1}{(6.28)\sqrt{.003}}$

$f = \frac{1}{(6.28)(.056)}$

$f = \frac{1}{.35}$

$f = 2.86\ Hz$

8. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{1543^2 + (25 - 47)^2}$

$Z = \sqrt{2380849 + (-22)^2}$

$Z = \sqrt{2380849 + 484}$

$Z = \sqrt{2381333}$

$Z = 1543.16\ ohms$

DECIBELS

Decibels (db) is a way of expressing an increase or decrease. In electronics, it is usually used to express the gain of a signal when amplified. Common logarithms are used to calculate db. It is necessary to know input and output in voltage (E), current (I), or power (P) to complete the formulas. Input and output can be thought of as a ratio, input: output.

$$db = 10 \times \text{Log} \frac{P_{out}}{P_{in}}$$

$$db = 20 \times \text{Log} \frac{E_{out}}{E_{in}}$$

$$db = 20 \times \text{Log} \frac{I_{out}}{I_{in}}$$

where:

I_{out} = output current
I_{in} = input current

P_{out} = output power
P_{in} = input power

E_{out} = output voltage
E_{in} = input voltage

Examples:

Given: voltage ratio 5:10
(this means voltage input = 5 volts and voltage output = 10 volts)

What is gain in decibels?

$db = 20 \times \text{Log} \frac{E_{out}}{E_{in}}$

$db = 20 \times \text{Log} \frac{10}{5}$

$db = 20 \times \text{Log} (2)$

$db = 20 \times .30$

$db = 6$

Given: current ratio .03:.02
(this means current input = .03 amps and current output = .2 amps)

What is gain in decibels?

$db = 20 \times \text{Log} \frac{I_{out}}{I_{in}}$

$db = 20 \times \text{Log} \frac{.2}{.03}$

$db = 20 \times \text{Log} (6.66)$

$db = 20 \times .823$

$db = 16.46$

Given: power ratio 200:250
(this means power input = 200 watts and power output = 250 watts)

What is gain in decibels?

$db = 10 \times \text{Log} \frac{P_{out}}{P_{in}}$

$db = 10 \times \text{Log} \frac{250}{200}$

$db = 10 \times \text{Log} 1.25$

$db = 10 \times .0969$

$db = .969$

PROBLEMS

Try the following problems. (REMEMBER: Use the Log key on your calculator when working the problems.)

1. Bad Ben's amplifier has an input current of .002 amps and an output current of .12 amps. What is the gain in decibels?

2. Doug had a loudspeaker with a power ratio of 5:6 (input : output). What is the gain in decibels?

3. Janice has a microphone with a current ratio of 10:12 (input : output). What is the gain in decibels?

SOLUTIONS

1. $db = 20 \times \text{Log} \frac{I_1}{I_2}$

$db = 20 \times \text{Log} \frac{12}{.002}$

$db = 20 \times \text{Log } 60$

$db = 20 \times 1.778$

$db = 35.56$

2. $db = 10 \times \text{Log} \frac{P_{out}}{P_{in}}$

$db = 10 \times \text{Log} \frac{6}{5}$

$db = 10 \times \text{Log } 1.2$

$db = 10 \times \text{Log } .079$

$db = .79$

3. $db = 20 \times \text{Log} \frac{I_{out}}{I_{in}}$

$db = 20 \times \text{Log} \frac{12}{10}$

$db = 20 \times \text{Log } 1.2$

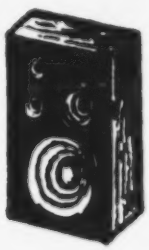
$db = 20 \times .079$

$db = 1.58$

4. Chip has an amplifier with a voltage ratio of 1:31.6 (input : output). What is the gain in decibels?

5. Gina wants to increase the volume level of her loudspeaker. She increased the input from 6 watts to 7 watts (Power ratio 6:7). It takes a change of at least 1 db to be discernible.

   a. What is the gain in db?



   b. Did Gina increase the volume enough to be discernible?

4. $db = 20 \times \text{Log} \frac{E_{out}}{E_{in}}$

$db = 20 \times \text{Log} \frac{31.6}{1}$

$db = 20 \times \text{Log } 31.6$

$db = 20 \times 1.5$

$db = 30$

5. a. $db = 10 \times \text{Log} \frac{P_{out}}{P_{in}}$

$db = 10 \times \text{Log} \frac{7}{6}$

$db = 10 \times \text{Log } 1.167$

$db = 10 \times .067$

$db = .67$

b. No

The following problems require an understanding of the metric system. Tell your teacher if you need assistance.

6. Dave had a loudspeaker with a power input of .05 kilowatts and a power output of 60,000 milliwatts.

   a. What is the power ratio (in watts)?

   b. What is the gain in decibels?

7. Rudy has a microphone with a current input of 4 milliamps a current output of .00024 kiloamps.

   a. What is the current ratio (in amps)?

   b. What is the gain in decibels?

8. Keith has an amplifier with a voltage input of 2000 millivolts, and a voltage output of .0632 kilovolts.

   a. What is the voltage ratio in volts?

   b. What is the gain in decibels?

6. a. .05 Kilowatts = 50 watts
.05 x 1000 = 50

60,000 milliwatts = 60 watts

$\frac{60,000}{1,000} = 60$

power ratio is 50:60

b. $db = 10 \times \text{Log} \frac{P_{out}}{P_{in}}$

$db = 10 \times \text{Log} \frac{60}{50}$

$db = 10 \times \text{Log} (1.2)$

$db = 10 \times .08$

$db = .8$

7. a. 4 milliamps = .004 amps

$\frac{4}{1000} = .004$ amps

.00024 kiloamps = .24 amps

.00024 x 1000 = .24 amps

current ratio is .004 : .24

b. $db = 20 \times \text{Log} \frac{I_{out}}{I_{in}}$

$db = 20 \times \text{Log} \frac{.24}{.004}$

$db = 20 \times \text{Log} (60)$

$db = 20 \times 1.8$

$db = 36$

8. a. 2000 millivolts = 2 volts

$\frac{2000}{1000} = 2$ volts

.0632 kilovolts = 63.2 volts

.0632 x 1000 = 63.2 volts

voltage ratio is 2 : 63.2

b. $db = 20 \times \text{Log} \frac{E_{out}}{E_{in}}$

$db = 20 \times \text{Log} \frac{63.2}{2}$

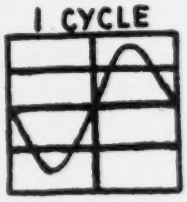
$db = 20 \times \text{Log} (31.6)$

$db = 20 \times 1.5$

$db = 30$

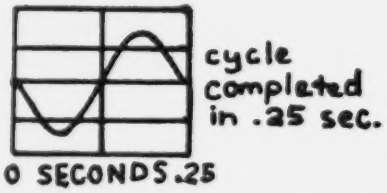
FREQUENCY

Use the following definitions and illustrations to help you understand how a simple mathematical formula can be used to determine the frequency and period of an AC waveform.

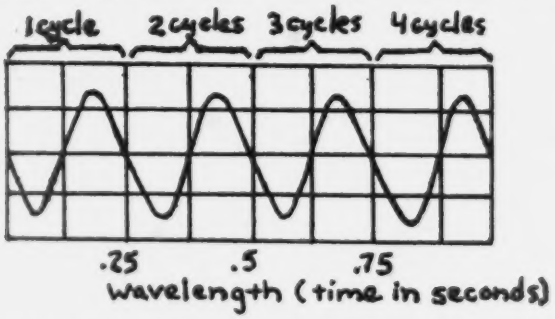


Cycle: A complete waveform building from zero to a maximum amplitude in one direction then back to zero and repeating in the opposite direction.

Period or Wavelength: The time required to complete one cycle.



Frequency: The number of cycles a wave travels per second, measured in hertz (Hz).



A range of frequencies is used in electronic circuits. Radios use a certain range, televisions another, and amplifiers still another. Frequency and period or wavelength are reciprocally related, making it easy to find one if we know the other using the formulas below.

$$f = \frac{1}{T}$$

f = frequency (measured in hertz)

and where T = period (wavelength)

$$T = \frac{1}{f}$$

1 Hz = 1 cycle per second

Example:

If the period is .25 seconds, what is the frequency?

$$f = \frac{1}{T}$$

$$f = \frac{1}{.25}$$

$f = 4$ Hz

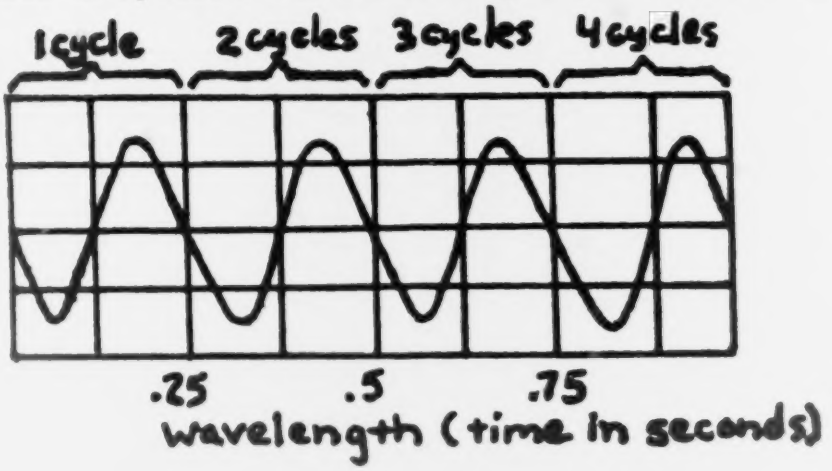
If the frequency is 4, what is the period?

$$T = \frac{1}{f}$$

$$T = \frac{1}{4}$$

$T = .25$ seconds

The number of cycles a wave travels per second, measured in hertz (Hz).



Problems

Work the following problems for practice using the formulas. Some of the problems require an understanding of the metric system. Tell your teacher if you need assistance with these problems.

1. What would the frequency of a wave be if the period (wavelength) was .5 seconds?

2. What would the period (wavelength) be if the frequency was 10?

3. Freddy is building a radio and needs to know the frequency of a station. He knows the period (wavelength) is 4 milliseconds (.004 seconds). What is the frequency?

4. If Freddy knows the period (wavelength) is 3 milliseconds, what would the frequency be?

SOLUTIONS

1. $f = \frac{1}{T}$

$f = \frac{1}{.5}$

$f = 2$ Hz

2. $T = \frac{1}{f}$

$T = \frac{1}{10}$

$T = .1$ seconds

3. $f = \frac{1}{.004}$

$f = \frac{1}{.004}$

$f = 250$ Hz

4. $f = \frac{1}{.003}$

$f = \frac{1}{.003}$

$f = 333.3$ Hz

5. James needs to know the period of a wave so he can work on the circuit that produces it. He knows the frequency is 10 KHz (10000 Hz). What is the period in seconds?

6. If James knows the frequency is 15 KHz, what would the period (wavelength) be in seconds?

7. Mary Belle is working on an electrical circuit. She knows the period (wavelength) is .002 milliseconds. What is the frequency in hertzs?

8. If Mary Belle knew the frequency was 3 megahertz, what would the period (wavelength) be in seconds?

5. $T = \frac{1}{f}$

$T = \frac{1}{10000}$

$T = .0001$ seconds

6. $T = \frac{1}{f}$

$T = \frac{1}{15000}$

$T = .00006$ seconds

7. $f = \frac{1}{T}$

.002 milliseconds = 2 seconds

$f = \frac{1}{2}$

$f = .5$ Hz

8. $T = \frac{1}{f}$

3 megahertz = 3,000,000 Hz

$T = \frac{1}{3{,}000{,}000}$

$T = .00000033$ seconds

9. Bill was confused when he read on his circuit that it used a frequency of 25 MHz. He did not understand what MHz meant.

   a. What does MHz mean?

   b. How many Hz is 25 MHz?

   c. What is the period (wavelength) associated with Bill's circuit?

10. Katherine has a circuit and needs to know the frequency it uses. She knows that the period associated with it is .0025 milliseconds. She needs to know how many megahertz it uses.

   a. Convert .0025 milliseconds to seconds.

   b. What frequency does the circuit use in hertz?

   c. What frequency does it use in megahertz (MHz)?

9. a. Megahertz

b. 25 MHz = 25,000,000 Hz

c. $T = \frac{1}{f}$

$T = \frac{1}{25,000,000}$

T = .00000004 seconds

10. a. .0025 milliseconds = 25 sec.

b. $f = \frac{1}{T}$

$f = \frac{1}{25}$

f = .04 Hz

c. .04 Hz = 40000 MHz

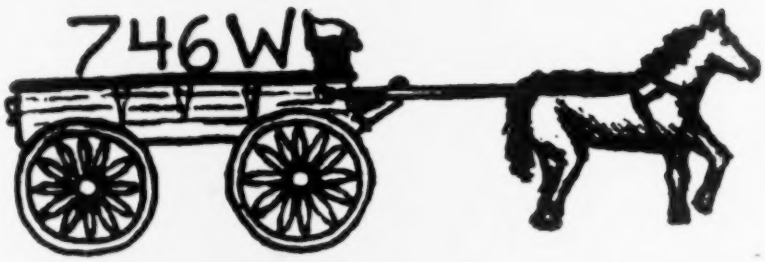
HORSEPOWER

Electric motors are used to do work, therefore, they develop power. Most motors are rated in horsepower (HP) with one horsepower equal to 746 watts (W).

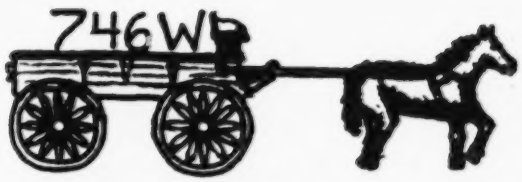
1 HP = 746 W

Example:

A motor that is rated at 2 HP has 1492 W. 746 x 2 = 1492 W



PROBLEMS



Work the following problems to get practice converting from watts to horsepower.

1. (a) Suppose you know that a particular motor has 3 HP. You also know that 1 HP = 746 watts. What mathematical operation would you use to find out how many watts it has (addition, subtraction, multiplication, division)? How many watts does it have?

   (b) You need a 2.5 HP motor for a project you are working on. You found an old motor in the garage that utilizes 1492 watts. What mathematical operation would you use to determine if the motor has enough HP? How many HP does it have? Do you need a smaller or larger motor?

2. Charles' new electric car has 8.2 HP, how many watts does it develop?

3. Farmer Jones connected a 1/2 HP motor and a 3/4 HP motor to his grain bin. How many watts of power does Farmer Jones use moving his grain?

SOLUTIONS

1. (a) multiplication

$746 \times 3 = 2238$ watts

(b) division

$$746\overline{)1492}^{\,2}$$

larger

2. Watts = HP x 746

Watts = 8.2 x 746

Watts = 6117.2

3. Watts = HP x 476

$$\text{Watts} = \left(\frac{1}{2} + \frac{3}{4}\right) \times 746$$

$$\text{Watts} = \frac{5}{4} \times 746$$

Watts = 932.5

OR

$$\text{Watts} = \left(\frac{1}{2} \times 746\right) + \left(\frac{3}{4} \times 746\right)$$

Watts = 373 + 559.5

Watts = 932.5

4. James has an old Steam Jenny that develops 4,103 watts. What would be the horsepower of his Steam Jenny?

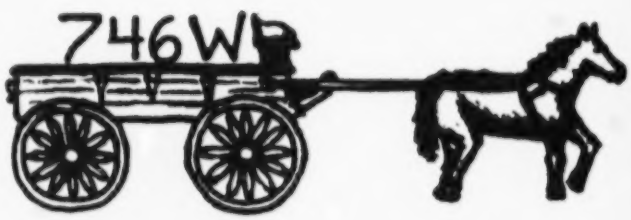
5. Rodney has a motor that is rated as having 8952 watts. How many horsepower does the motor have?

6. Nola has four motors. The first one has .5 horsepower, the second one has 1.5 horsepower, the third one has 2 horsepower, and the fourth has 2.5 horsepower.

   a. What is the total horsepower of the motors?

   b. How many watts does each motor have?

   c. What is the total amount of watts the motors have?



4. $HP = \frac{Watts}{746}$

$HP = \frac{4103}{746}$

$HP = 5.5$

5. 1 HP = 746 W

$\frac{8952}{746} = 12$ HP

6. a. .5
1.5
2.0
2.5
6.5 HP

b. Motor 1 $\frac{746}{2} = 373$ W

Motor 2 $746 \times 1.5 = 1119$ W

Motor 3 $746 \times 2 = 1492$ W

Motor 4 $746 \times 2.5 = 1865$ W

c. 373
1119
1492 or $746 \times 6.5 = 4849$ W
1865
4849 W

IMPEDANCE

Some electronic circuits contain resistance (R) and reactance (X). Both are oppositions to current flow and are measured in ohms (Ω). Reactance is opposition offered by an inductor or capacitor and is referred to as inductive reactance (X_L) and capacitive reactance (X_C).

Because of a time factor involved with AC voltage, the total opposition or impedance (Z) in a series circuit is found by using the formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where Z = impedance

R = resistance

X_L = inductive reactance

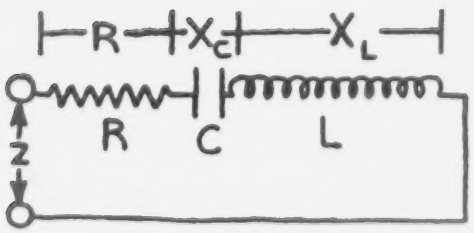
X_C = capacitive reactance

If only resistance and inductance are used in the circuit impedance (Z) the formula would be:

$$Z = \sqrt{R^2 + X_L{}^2}$$

When only resistance and capacitance are used in the circuit impedance formula would be:

$$Z = \sqrt{R^2 + X_C{}^2}$$



Examples:

Find impedance given:

A. resistance of 10 ohms
inductive reactance of 25 ohms
capacative reactance of 20 ohms

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{10^2 + (25 - 20)^2}$$

$$Z = \sqrt{10^2 + 5^2}$$

$$Z = \sqrt{100 + 25}$$

$$Z = \sqrt{125}$$

$$Z = 11.18 \text{ ohms}$$

B. resistance of 2200 ohms
inductive reactance of 1200 ohms

$$Z = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{2200^2 + 1200^2}$$

$$Z = \sqrt{4840000 + 1440000}$$

$$Z = \sqrt{6280000}$$

$$Z = 2505.99 \text{ ohms}$$

C. resistance of 9 ohms
capacative reactance of 6 ohms

$$Z = \sqrt{R^2 + X_C^2}$$

$$Z = \sqrt{9^2 + 6^2}$$

$$Z = \sqrt{81 + 36}$$

$$Z = \sqrt{117}$$

$$Z = 10.8 \text{ ohms}$$

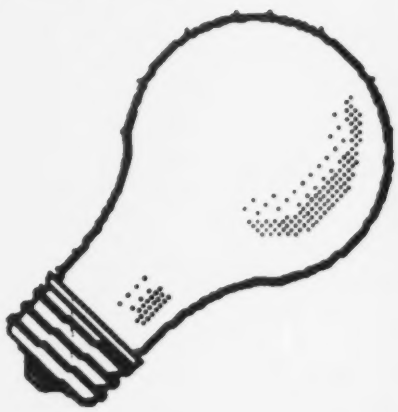
Problems

Work the following problems dealing with impedance.

1. Joe Cool has an electronic light sensor with 20 ohms of resistance (R), 40 ohms of inductive reactance (X_L) and 50 ohms of capacitive reactance (X_C). How much impedence (Z) is in his circuit?

2. Joe has another light sensor with 30 ohms of resistance (R) and 60 ohms of inductive reactance (X_L). How much impedance (Z) is in his circuits?

3. Another light sensor has 15 ohms of resistance (R) and 45 ohms of capacitance reactance (X_C). How much impedance (Z) is in his circuit?



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SOLUTIONS

1. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{20^2 + (40 - 50)^2}$

$Z = \sqrt{20^2 + (-10)^2}$

$Z = \sqrt{400 + 100}$

$Z = \sqrt{500}$

$Z = 22.36\ \Omega$

2. $Z = \sqrt{R^2 + X_L{}^2}$

$Z = \sqrt{30^2 + 60^2}$

$Z = \sqrt{900 + 3600}$

$Z = \sqrt{4500}$

$Z = 67.08\ \Omega$

3. $Z = \sqrt{R^2 + X_C{}^2}$

$Z = \sqrt{15^2 + 45^2}$

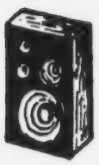
$Z = \sqrt{225 + 2025}$

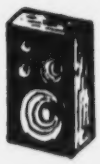
$Z = \sqrt{2250}$

$Z = 47.43\ \Omega$

4. Sweet Jim has a circuit with 2500 ohm resistor and a coil which offers 1500 ohms of inductive reactance. What is the impedance?

5. Henry wanted to know what the impedance was on the new speakers he just purchased. The schematic told him the resistance was 7 ohms and the capacitive reactance was 5 ohms. What was the impedance?





6. Maynard has an electronic beeper. He needs to know how much resistance it has. He knows it has 30 ohms of inductive reactance, 40 ohms of capacitive reactance and 21.5 ohms of impedance.

4. $Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{2500^2 + 1500^2}$

$Z = \sqrt{6250000 + 2250000}$

$Z = \sqrt{8500000}$

$Z = 2915.48$ ohms

5. $Z = \sqrt{R^2 + X_C^2}$

$Z = \sqrt{7^2 + 5^2}$

$Z = \sqrt{49 + 25}$

$Z = \sqrt{74}$

$Z = 8.6$ ohms

6. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{R^2 + (30 - 40)^2}$

$Z = \sqrt{R^2 + (-10)^2}$

$Z = \sqrt{R^2 + 100}$

$(21.5)^2 = R^2 + 100$

$462.25 = R^2 + 100$

$462.25 - 100 = R^2$

$362.25 = R^2$

$\sqrt{362.25} = R$

$19.03 = R$

7. Linda has an electronic beeper also. She knows it has 20 ohms of inductive reactance, 20 ohms of impedance and 18 ohms of resistance. How much capacitive reactance does it have?

8. Nelson also has an electronic light sensor. He knows it has 10 ohms of impedance, 9 ohms of resistance and 20 ohms of capacitive reactance. How much inductive reactance does it have?

7. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$20 = \sqrt{18^2 + (20 - X_C)^2}$

$20 = \sqrt{324 + (20 - X_C)^2}$

$20^2 = 324 + (20 - X_C)^2$

$400 = 324 + (20 - X_C)^2$

$400 - 324 = (20 - X_C)^2$

$76 = (20 - X_C)^2$

$\sqrt{76} = 20 - X_C$

$8.717 = 20 - X_C$

$8.717 - 20 = -X_C$

$-11.283 = -X_C$

$11.283 = X_C$

8. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$10 = \sqrt{9^2 + (X_L - 20)^2}$

$10 = \sqrt{81 + (X_L - 20)^2}$

$10^2 = 81 + (X_L - 20)^2$

$100 = 81 + (X_L - 20)^2$

$100 - 81 = (X_L - 20)^2$

$19 = (X_L - 20)^2$

$\sqrt{19} = X_L - 20$

$4.358 = X_L - 20$

$4.358 + 20 = X_L$

$24.358 = X_L$

9. Bruce has a circuit with a 2350 ohm resistor and has an impedance of 3000 ohms. What is the inductive reactance?

10. Edgar wants to know the capacitive reactance on his new speakers. He knows the resistance is 5 ohms and the impedance is 8 ohms.

9. $Z = \sqrt{R^2 + X_L^2}$

$3000 = \sqrt{2350^2 + X_L^2}$

$3000 = \sqrt{5522500 + X_L^2}$

$3000^2 = 5522500 + X_L^2$

$9000000 = 5522500 + X_L^2$

$9000000 - 5522500 = X_L^2$

$3477500 = X_L^2$

$\sqrt{3477500} = X_L$

$1864.8 = X_L$

10. $Z = \sqrt{R^2 + X_C^2}$

$8 = \sqrt{5^2 + X_C^2}$

$8 = \sqrt{25 + X_C^2}$

$8^2 = 25 + X_C^2$

$64 = 25 + X_C^2$

$64 - 25 = X_C^2$

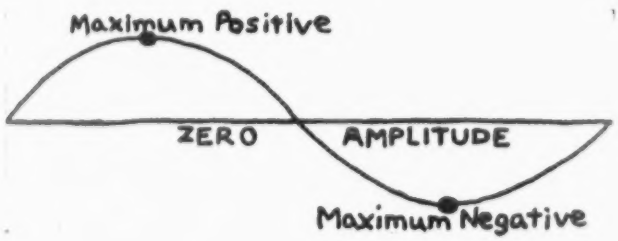
$39 = X_C^2$

$\sqrt{39} = X_C$

$6.244 = X_C$

INSTANTANEOUS SINE VOLTAGE

Radio waves or sine waves vary in amplitude as well as frequency. During each cycle an AC voltage (radio wave) will reach a maximum amplitude (peak) in a positive direction and then in a negative direction.



The amplitude stays at maximum (peak) only instantaneously and then starts to decrease. Since the amplitude changes constantly, we need to have some way of putting a value on the wave. This is accomplished by using percentages.

The average value (AV) of all instantaneous voltages for one-half cycle [one maximum (peak) voltage] is always equal to 63.7% of the maximum (peak) value.

The effective value (EFF) is always equal to 70. 7% of the maximum (peak) value.

The average (AV) and effective (EFF) values are important because the effective value of alternating current is equal to direct current in the amount of work it will do. The average value is always less than the actual amount of work that will be accomplished.

EFF = 70.7% of PK or .707 x PK

AV = 63.7% of PK or .637 x PK

Example:

The peak value of a wave is 125 volts.

effective value = .707 x 125
88.375 volts

average value = .637 x 125
79.625 volts

PROBLEMS

1. Radio Sam knows the peak (PK) value of a wave is 150 volts. What is the effective value?

2. Karen knows the peak (PK) value of a wave is 200 volts. What is the average value of the wave?

3. Justin knows that the peak value of a wave is 114 volts.

   a. What is the effective value?

   b. What is the average value?

4. You know the average value of a wave is 75 volts.

   a. What is the peak value?

   b. What is the effective value?

5. You know the effective value of a wave is 50 volts.

   a. What is the peak value?

   b. What is the average value?

SOLUTIONS

1. EFF = 70.7% of PK =

   EFF = .707 x 150 =

   EFF = 106.05 volts

2. AV = 63.7% of PK =

   AV = .637 x 200 =

   AV = 127.4 volts

3. a. EFF = .707 x PK

   EFF = .707 x 114

   EFF = 80.598 volts

   b. AV = .637 x PK

   AV = .637 x 114

   AV = 72.618 volts

4. a. AV = .637 x PK

   75 = .637 x PK

   $\frac{75}{.637} = PK$

   117.73 volts = PK

   b. EFF = .707 x PK

   EFF = .707 x 117.73

   EFF = 83.235 volts

5. a. EFF = .707 x PK

   50 = .707 x PK

   $\frac{50}{.707} = PK$

   70.72 = PK

   b. AV = .637 x PK

   AV = .637 x 70.72

   AV = 45.048 volts

The following problems require an understanding of the metric system. Tell your teacher if you need assistance.

6. J. D. knows the peak value of a wave is .4 Kilovolts.

   a. What is the effective value in volts?

   b. What is the average value in volts?

7. Kelly knows the average value of a wave is 4000 millivolts.

   a. What is the peak value in volts?

   b. What is the effective value in volts?

6. .4 Kilovolts = 400 volts

a. EFF = .707 x PK

EFF = .707 x 400

EFF = 282.8 volts

b. AV = .637 x PK

AV = .637 x 400

AV = 254.8 volts

7. 4000 millivolts = 4 volts

a. AV = .637 x PK

4 = .637 x PK

$\frac{4}{.637}$ = PK

6.279 volts = PK

b. EFF = .707 x PK

EFF = .707 x 6.279

EFF = 4.439 volts

METRICS

In electronics the metric system is used to express quantities for units of measurement such as ohms, volts, amperes, and watts.

The symbol for each basic unit of measurement is:

w = Watts
v = volts
a = Amperes (amps)
Ω (Greek letter for "Omega") = Ohms

The metric system uses:

K = Kilo which means thousands (1,000)
M = Mega which means millions (1,000,000)
m = Milli which means thousandths of (.001)
u= Micro which means millionths of (.000001)
P = Pico which means trillionth of (.000000000001)

To Change	Into	Multiply by	Divide by
basic unit	milli	10^3 (1000)	
Kilo	basic unit	10^3	
basic unit	micro	10^6 (1,000,000)	
Mega	basic unit	10^6	
basic unit	pico	10^{12}	
milli	basic unit		10^3 (1000)
basic unit	Kilo		10^3
micro	basic unit		10^6 (1,000,000)
basic unit	Mega		10^6
pico	basic unit		10^{12} (1,000,000,000,000)

Examples:

100 ma = .1 a
.2 a = 200 ma
7.5 Mohm = 7,500,000 ohms (Ω)
4 mw = .004 w
4 Kohm = 4000 ohms (Ω)
2 pv = .000000000002 V
100 mv = .1 v
80 pv = (.00000000008 v)
1 v = 1000000000000 pv
.005 w = 5 mw
1 uv = .000001 w
1 pv = .000000000001 v
1 a = 1000 ma
1 ma = .001 a
1 a = 1000000000000 pa
1 mv = .001 v
1000 mv = 1 v
1 pa = .000000000001 a
1000 uw; 1 mw = .001 w

1. Following are some practice problems. Convert the following from metric unit to basic unit.

1. 4.7 mv = _____v

2. 500 ma = _____a

3. 75 mw = _____w

4. 470 pa = _____a

5. 3 K Ω = _____Ω

6. 4 M Ω = _____Ω

Convert the following from basic unit to the metric unit:

7. .004 v = _____mv

8. .000008 a = _____ma

9. .00000000045 w = _____mw

10. 5 w = _____mw

11. .06 v = _____pv

12. .007 a = _____ma

13. 4500 Ω = _____K

14. 1000 Ω = _____M

15. 27000 Ω = _____K

16. 4700000 Ω = _____M

SOLUTIONS

1. .0047 v
2. .5 a
3. .075 w
4. .000000000470 a
5. 3000 Ω
6. 4000000 Ω
7. 4 mv
8. .008 ma
9. .00000045 mv
10. 5000 mv
11. 60000000000 pv
12. 7 ma
13. 4.5 K Ω
14. .001 m Ω
15. 27 k Ω
16. 4.7 m Ω

II. Work the following problems using the conversion you learned in the previous exercises.

1. Johnny Brainstorm wanted to know how many watts his personal computer required. The manual told him it had four printed circuit cards. One used 4 ma, another used 60 ma, the third used 470 ma and the final card used .5 a. What was the total amps of Brainstorm's computer?

2. A certain household circuit can handle a maximum load of 1800 w. If an electric motor using .76 kw, two (2) 150 w lightbulbs, a .00032 Mw hot plate and a 2200 mw night light are all on the same curcuit, can they all be run at the same time? How many watts would they use?

II.

1. 1.034 a

.5a = 500 ma
470 ma
60 ma
4 ma
1034 ma = 1.034 a

2. 1800 w given
.76 kw = 760 w
2@ 150 w = 300 w
.000320 mw = 320 w
2200 mw = 2.2 w
1382.2 w is less than 1800 w
so they can be run at the same time.

3. Bennie wants to know how much resistance is in his circuit. He just needs to add up the resistance of each appliance connected, but the resistance of each appliance is measured in a different metric unit. Bennie needs help.

The appliances have resistance as follows:

fan 3 ma
razor 400,000,000 pa
radio .04 Ka
lamp 300 ua
hair dryer .025 Ma

a. What is the resistance of each appliance in amps (a)?

b. What is the total resistance of all the appliances (add) in

1. amps?

2. Kiloamps?

3. Megamps?

3. A. fan 3 ma = .003 a

$10^{\overset{3}{3}} = .003$

razor 400,000,000 pa = .4 a

$\frac{400,000,000}{10^{12}} = .0004$

radio .04 Ka = 40 a

$.04 \times 10^{3} = 40$

lamp 300 ua = .0003 a

$\frac{300}{10^{6}} = .0003$

hair dryer .025 Ma = 25000 a

$.025 \times 10^{6} = 25000$

B. a. 25040.4033 a

b. 25040.4033 a = 25.040433 Ka

$\frac{25040.4033}{10^{3}} = 25.040433$ a

c. 25040.4033 a = .025040403 Ma

$\frac{25040.4033\ a}{10^{6}} = .025040403$

OHM'S LAW

George Ohm, a German scientist, discovered the relationship between current, voltage, and resistance: "The current is directly proportional to the voltage and inversely proportional to the resistance."

Using Ohm's Law

This would tell us that anytime we know the values of any two of these (current, voltage, or resistance) we can figure the other one by using one of the formulas below:

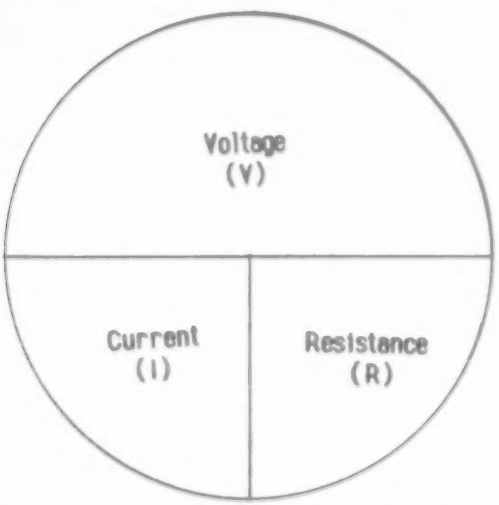
$$\text{Current (I)} = \frac{\text{voltage (V)}}{\text{resistance (R)}} \quad \text{or} \quad I = \frac{V}{R}$$

$$\text{Voltage (V)} = \text{current (I)} \times \text{resistance (R)} \quad \text{or} \quad V = IR$$

$$\text{Resistance (R)} = \frac{\text{voltage (V)}}{\text{current (I)}} \quad \text{or} \quad R = \frac{V}{I}$$

Current (I) is measured in amperes (a).
Voltage (V) is measured in volts (V).
Resistance (R) is measured in ohms (Ω).

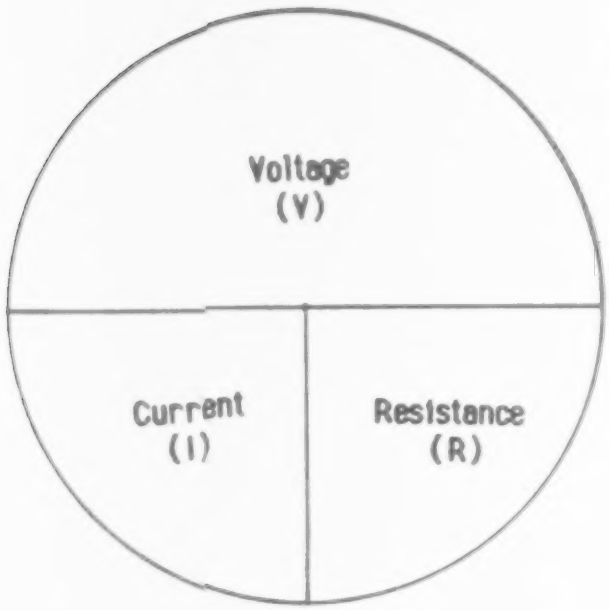
An easy way to remember these formulas is to construct an Ohm's Law circle like the one below:



To use it, put your thumb over the quantity you want to find and do the multiplication or division indicated. Try it. It works.

Examples:

Given :	Given :	Given:
Current = 3 amps	Current = 2 amps	Voltage = 240 volts
Voltage = 120 volts	Resistance = 6 ohms	Resistance = 12 ohms
Resistance = ?	Voltage = ?	Current = ?
$R = \frac{V}{I}$	$V = IR$	$I = \frac{V}{R}$
$R = \frac{120}{3}$	$V = 2 \times 6$	$I = \frac{240}{12}$
R = 40 ohms (Ω)	V = 12 volts (V)	I = 20 amps (a)



Problems

Do the problems on the next two pages. There are two problems each for the three things we want to find. First, you try them without help, then look on the back of the pages for the correct answers and solutions.

1. An electric apparatus has a resistance of 60 ohms. How much voltage must be applied to the device to cause 2.0 amperes of current to flow?

2. The current flowing through a lamp is known to be 1.25 a. Its resistance is 96 Ω. What voltage is necessary to keep the lamp burning as it is now?

3. Jim Jones has a table lamp which has a resistance of 85 ohms. How much current flows through his lamp when it is plugged into a 120 volts power source?

Solutions

1. Given: R = 60

   I = 2.0 A

   Find: V

   Formula: V = IR

   Solution: V = 2.0 A x 60 Ω = 120 V

   Answer: Voltage applied to the device must be 120 V.

2. Given: R = 96 Ω

   $I = \frac{1}{25}$ A

   Find: V

   Formula: V = IR

   Solution: V = 1.25 A x 96 Ω = 120 V

   Answer : 120 V are necessary to maintain lamp burning as it is.

3. Given: R = 85 Ω

   V = 120 V

   Find: I

   Formula: $I = \frac{V}{R}$

   Solution: I = 120 V = 1.41 A

   Answer: Current through the lamp is 1.41 A.

4. An electric toaster has a resistance of 150 Ω and is on a 110 volts power line. How much current does it draw?

5. When connected to a 120 volts power source, a lamp will allow .085 amperes of current. What is the resistance of the lamp?

6. A desk light has specifications indicating .08 amperes of current when 120 volts are applied to it. What is its resistance?

4. Given: $R = 150\ \Omega$

$V = 110\ V$

Find: I

Formula: $I = \frac{V}{R}$

Solution: $I = \frac{110\ V}{150\ \Omega} = .733\ A$

Answer: The toaster draws .733 A.

5. Given: $I = .085$ ampere (A)
$V = 120$ volts (V)

Find: R

Formula: $R = \frac{V}{I}$

Solution: $R = \frac{120\ V}{.085\ A} = 1141.2$ ohms (Ω)

Answer: Resistance of the lamp is 141.2 ohms.

6. Given: $I = .8$ ampere (A)

$V = 120$ volts (V)

Find: R

Formula: $R = \frac{V}{I}$

Solution: $R = \frac{120\ V}{.8\ A} = 150$ ohms (Ω)

Answer: Resistance of desk light is 150 ohms.

OP - AMPLIFIERS

Operational Amplifiers (OP-AMP) are solid-state integrated circuit amplifiers that use external feedback to control their gain (increase in signal level or voltage). The amplifiers are categorized into four types based on the different characteristics of their integrated circuits (chips). The types are:

inverting amp
noninverting amp
DC summing amp
differential amp

Each type uses a different formula to calculate voltage gain or output.

$$A_v = -\frac{R_2}{R_1}$$

Inverting Amp

$$A_v = \frac{R_1 + R_2}{R_1}$$

Noninverting Amp

$$V_{out} = -R_4 \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$$

DC Summing Amp

$$V_{out} = \frac{R_2}{R_1} (V_2 - V_1)$$

Differential Amp

Symbols used in the formulas are:

A_v = voltage gain

R_1, R_2, R_3, etc. = resistance of resistor 1, 2, 3, etc.

V_1, V_2, V_3, etc. = voltage of resistor 1, 2, 3, etc. (voltage drop)

V_{out} = output voltage

Examples:

Given: R_1 = 1000 ohms V_1 = 20

R_2 = 3000 ohms V_2 = 35

R_3 = 5000 ohms V_3 = 24

R_4 = 7000 ohms

Voltage gain of inverting amp

$$A_V = -\frac{R_2}{R_1}$$

$$A_V = \frac{-3000}{1000}$$

$$A_V = -3$$

Voltage gain of noninverting amp

$$A_V = \frac{R_1 + R_2}{R_1}$$

$$A_V = \frac{1000 + 3000}{1000}$$

$$A_V = \frac{4000}{1000}$$

$$A_V = 4$$

Output voltage of summing amp

$$V_{out} = -R_4 \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$$

$$V_{out} = -7000 \left(\frac{20}{1000} + \frac{35}{3000} + \frac{24}{5000} \right)$$

$$V_{out} = -7000\ (.02 + .01166 + .0048)$$

$$V_{out} = -7000\ (.03646)$$

$$V_{out} = -255.22$$

Output voltage of differential amp

$$V_{out} = \frac{R_2}{R_1} (V_2 - V_1)$$

$$V_{out} = \frac{3000}{1000} (35 - 20)$$

$$V_{out} = 3\ (15)$$

$$V_{out} = 45$$

PROBLEMS

Now do the following problems to see how these formulas work:

Alton T. has been given a choice of using an inverting, noninverting, or a summing inverting amplifier. His resistors have R_1 which is 2000 ohms, R_2 which is 4000 ohms, R_3 which is 6000 ohms and R_4 which is 20000 ohms.

1. What would be the voltage gain (A_v) of the inverting amp?

2. What would be the voltage gain of the noninverting amp?

3. If R_1, R_2, and R_3, each had voltage drops of 50 volts, what would be the output voltage of Alton T.'s summing amp?

4. What if Alton T. wanted to use a differential amplifier? If V_1 = 100 volts and V_2 = 200 volts, what would his output be?

SOLUTIONS

1. inverting $A_v = \frac{-R_2}{R_1}$

$A_v = \frac{-4000}{2000}$

$A_v = -2$

2. noninverting $A_v = \frac{R_1 + R_2}{R_1}$

$A_v = \frac{2000 + 4000}{2000}$

$A_v = \frac{6000}{2000}$

$A_v = 3$

3. $V_{out} = -R_4 \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$

$V_{out} = -20000 \left(\frac{50}{2000} + \frac{50}{4000} + \frac{50}{6000} \right)$

$V_{out} = -20000 \ (.025 + .0125 + .0083)$

$V_{out} = -20000 \ (.0458)$

$V_{out} = -916$

OR

$V_{out} = -20000 \left(\frac{50}{2000} + \frac{50}{4000} + \frac{50}{6000} \right)$

$V_{out} = -20000 \left(\frac{300}{12000} + \frac{150}{12000} + \frac{100}{12000} \right)$

$V_{out} = -20000 \ \frac{550}{12000}$

$V_{out} = -20000 \ (.0458)$

$V_{out} = -916$

4. $V_{out} = \frac{R_2}{R_1} (V_2 - V_1)$

$V_{out} = \frac{4000}{2000} (200-100)$

$V_{out} = \frac{4000}{2000} (100)$

$V_{out} = 2 \ (100)$

$V_{out} = 200$

OR

$V_{out} = \frac{4000}{2000} (200-100)$

$V_{out} = \frac{4000}{2000} \left(\frac{100}{1} \right)$

$V_{out} = \frac{400}{2}$

$V_{out} = 200$

Marty wants to know the voltage gain and output of different types of amplifiers. He knows that R_1 is 2500 ohms, R_2 is 1450 ohms, R_3 is 1600 ohms and R_4 is 1920 ohms. Marty also knows that R_1 has a voltage drop of 24 volts and R_2 and R_3 have voltage drops of 48 volts each.

5. What would be the voltage gain of an inverting amp?

6. What would be the voltage gain of a noninverting amp?

7. What would be the voltage drop in a summing amp?

8. What would be the voltage drop in a differential amp?

5. $A_V = \frac{-R_2}{R_1}$

$A_V = \frac{-1450}{2500}$

$A_V = -.58$

6. $A_V = \frac{R_1 + R_2}{R_1}$

$A_V = \frac{2500 + 1450}{2500}$

$A_V = \frac{3950}{2500}$

$A_V = 1.58$

7. $V_{out} = -R_4 \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$

$V_{out} = -1920 \left(\frac{24}{2500} + \frac{48}{1450} + \frac{48}{1600} \right)$

$V_{out} = -1920 (.0096 + .0331 + .03)$

$V_{out} = -1920 (.0727)$

$V_{out} = -139.584$

8. $V_{out} = \frac{R_2}{R_1} (V_2 - V_1)$

$V_{out} = \frac{1450}{2500} (48 - 24)$

$V_{out} = .58 (24)$

$V_{out} = 13.92$

REACTANCE

Capacitors and coils are electrical components that vary as applied voltage amplitude or frequency varies. Capacitors store energy when an electronic charge is forced onto its plates by some energy source such as a battery. The basic unit of capacitance is measured in farads (F). We use the following formula to measure capacitance:

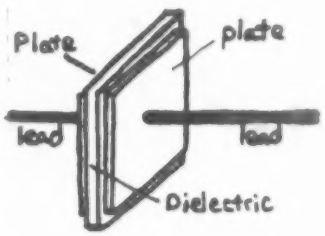
$$C = \frac{1}{2\pi f X_C}$$

where: C = capacitance (capacitor) measured in farads

f = frequency measured in Hz

X_C = capacitive reactance (opposition of a capacitor) measured in ohms

$\pi = 3.14$



Capacitor

Coils serve as inductors in an electrical circuit and oppose sudden changes in current by restricting the rate at which the current can increase. The basic unit of inductance is the henry (h). We use the following formula to measure inductance:

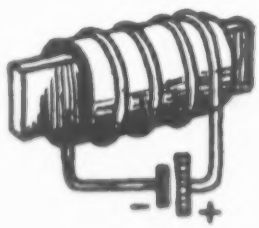
$$L = \frac{X_L}{2\pi f}$$

where: L = inductance (inductor or coil) measured in henries

X_L = inductive reactance (opposition of an inductor) measured in ohms

f = frequency measured in Hz

$\pi = 3.14$



Coil

90

Examples:

A. Compute capacitance using the following information.

Frequency = 200 Hz
capacitive reactance = 2 ohms

$$C = \frac{1}{2 \pi f X_C}$$

$$C = \frac{1}{2 (3.14) (200) (2)}$$

$$C = \frac{1}{6.28 (200) (2)}$$

$$C = \frac{1}{1256 (2)}$$

$$C = \frac{1}{2512}$$

C = .0004 farads or 400 microfarads (mfds)

B. Compute inductance using the following information.

Frequency = 30 Hz
inductive reactance = 10 ohms

$$L = \frac{X_L}{2 \pi f}$$

$$L = \frac{10}{2 (3.14) (30)}$$

$$L = \frac{10}{6.28 (30)}$$

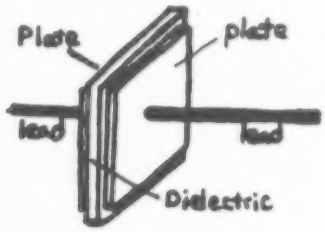
$$L = \frac{10}{188.4}$$

L = .053 henries

Problems

1. When John had noise in his radio he found the frequency to be 400 Hz and he knew he needed 5 ohms of opposition to eliminate it. What value capacitor (capacitance) will John need?

2. George needs to know how much opposition is in his radio circuit so he can use the right size fuses and wire. He knows the frequency is 1000 Hz and the capacitor is 40 microfarad (.00004 farads). What is the opposition?



SOLUTIONS

1. $f = 400$ Hz
   $X_C = 5$ ohms

$$C = \frac{1}{2\pi f X_C}$$

$$C = \frac{1}{2(3.14)(400)(5)}$$

$$C = \frac{1}{6.28(400)(5)}$$

$$C = \frac{1}{2512(5)}$$

$$C = \frac{1}{12560}$$

$C = .0000796$ farads

2. $f = 1000$Hz
   $C = .00004$ farads

$$X_C = \frac{1}{2\pi f C}$$

$$X_C = \frac{1}{2(3.14)(1000)(.00004)}$$

$$X_C = \frac{1}{6.28(1000)(.00004)}$$

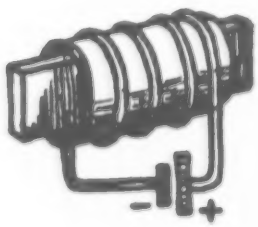
$$X_C = \frac{1}{6280(.00004)}$$

$$X_C = \frac{1}{.2512}$$

$X_C = 3.98$ ohms

3. Candy needs a coil in a light circuit to reduce the brightness. If the frequency is 60 Hz and the coil needs to offer 20 ohms of inductive reactance, what value inductor (coil) will she need?

4. Sara has a light circuit with a frequency of 45 Hz, she knows that the value of the coil (inductor) is .042 h. How much inductive reactance is there?



3. $f = 60$ Hz
$X_L = 20$ ohms

$$L = \frac{X_L}{2\pi f}$$

$$L = \frac{20}{2\pi\ (60)}$$

$$L = \frac{20}{2\ (3.14)\ (60)}$$

$$L = \frac{20}{6.28\ (60)}$$

$$L = \frac{20}{376.8}$$

$L = .053$ henries

4. $f = 45$ Hz
$L = .042$ henries

$$X_L = 2\pi f L$$

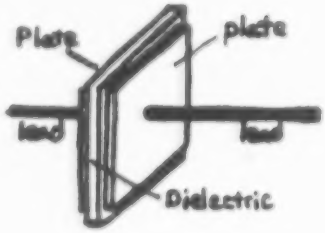
$$X_L = 2\ (3.14)\ (45)\ (.042)$$

$$X_L = (6.28)\ (45)\ (.042)$$

$$X_L = 282.6\ (.042)$$

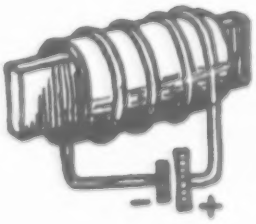
$X_L = 11.8692$ ohms

5. Jason had a radio. He knew it used a .00000525 farads capacitor and had 4 ohms of opposition. What is the frequency of Jason's radio?



6. Janie knows she has .5 ohm of opposition in her radio circuit and that it uses a .00005 farads capacitor. What is the frequency?

7. Vivian replaced a coil in her light circuit with a valve of .05 h. She knows that the coil offers 15 ohms of inductive reactance. What is the frequency?



5. $X_C = 4$ ohms

$C = .00000525$ farads

$f = ?$

$$C = \frac{1}{2\pi f X_C}$$

$$.00000525 = \frac{1}{(2\pi) f (4)}$$

$$.00000525 = \frac{1}{(6.28)(f)(4)}$$

$$.00000525 = \frac{1}{25.12 f}$$

$$(25.12)(.00000525) = \frac{1}{f}$$

$$.000131 = \frac{1}{f}$$

$$f = \frac{1}{.000131}$$

$f = 7633.58$ Hz

6. $X_C = 5$ ohms

$C = .00005$ farads

$f = ?$

$$C = \frac{1}{2\pi f X_C}$$

$$.00005 = \frac{1}{2\pi f (5)}$$

$$.00005 = \frac{1}{(6.28)(f)(5)}$$

$$.00005 = \frac{1}{31.4 f}$$

$$(31.4)(.00005) = \frac{1}{f}$$

$$.00157 = \frac{1}{f}$$

$$f = \frac{1}{.00157}$$

$f = 636.94$ Hz

7. $L = .05$ h

$X_L = 15$ ohms

$f = ?$

$$L = \frac{X_L}{2\pi f}$$

$$.05 = \frac{15}{2\pi f}$$

$$.05 = \frac{15}{6.28(f)}$$

$$6.28(.05) = \frac{15}{f}$$

$$3.14 = \frac{15}{f}$$

$$\frac{.314}{15} = \frac{1}{f}$$

$$.0209 = \frac{1}{f}$$

$$f = \frac{1}{.0209}$$

$f = 47.846$ Hz

8. For additional practice, work the following problems using the information given.

a. $f = 10$ Hz

$X_C = 2$ ohms

$C = ?$

b. $X_L = 12$ ohms

$f = 50$ Hz

$L = ?$

c. $L = .045$ henries

$X_L = 10$ ohms

$f = ?$

8. a. $C = \frac{1}{2\pi f X_C}$

$C = \frac{1}{2\pi (10)(2)}$

$C = \frac{1}{(6.28)(10)(2)}$

$C = \frac{1}{125.6}$

$C = .0079$ farads

b. $L = \frac{X_L}{2\pi f}$

$L = \frac{12}{2\pi (50)}$

$L = \frac{12}{(6.28)(50)}$

$L = \frac{12}{314}$

$L = .0382$ henries

c. $L = \frac{X_L}{2\pi f}$

$.045 = \frac{10}{2\pi f}$

$.045 = \frac{10}{6.28 f}$

$6.28 (.045) = \frac{10}{f}$

$.2826 = \frac{10}{f}$

$\frac{.2826}{10} = \frac{1}{f}$

$.02826 = \frac{1}{f}$

$f = \frac{1}{.02826}$

$f = 35.38$ Hz

RECTIFICATION

(MAKING DC FROM AC)

Alternating current (AC) must be changed to direct current (DC) to operate most electronic components. This is accomplished by means of a rectifier circuit, more often called a power supply. The amount of DC that is produced by a power supply depends upon two factors, the type of power supply and the voltage applied.

AC voltage is usually given in the unit of RMS (example 120 Vrms) to represent how it relates to an equal amount of DC.

To convert AC rms to AC peak (PK) we use the formula: $V_{pk} = 1.414\ V_{rms}$

To convert AC pk to AC rms, we use the formula: $V_{rms} = \frac{V_{pk}}{1.414}$

There are two basic types of power supplies, halfwave and fullwave. The formulas for finding the DC output of a halfwave power supply when the input is known or the AC input when the output is known are:

$V_{dc} = .318\ V_{pk}$

$V_{pk} = \frac{V_{dc}}{.318}$

Where:

Vdc = output DC voltage

Vpk = peak AC input voltage

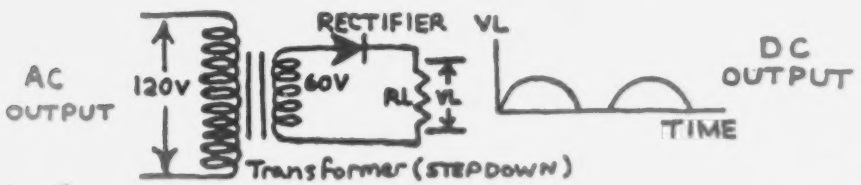
The formulas used in fullwave rectifier circuits are:

$V_{dc} = .636\ V_{pk}$

$V_{pk} = \frac{V_{dc}}{.636}$

Example:

Below is a diagram of a rectifier circuit. From the diagram we see that 120 volts of AC current is put into the circuit. It then goes through a transformer and is stepped down or reduced to 60 volts before going through the rectifier.



To find DC voltage output (Vdc), of a halfwave power supply, we use the formula: Vdc = .318 Vpk

Vpk is not given. We can calculate it using the formula: Vpk = 1.414 Vrms

Vpk = 1.414 x 60

Vpk = 84.84 volts

Vdc = .318 Vpk

Vdc = .318 x 84.84 V

Vdc = 26.98 V

Problems

Try the following problems.

1. Katherine has a rectifier circuit. She knows it has 30 Vrms. What will the DC output be:

   a. of a fullwave power supply?

   b. of a halfwave power supply?

2. Lee is trying to fix a rectifier circuit. He knows that Vdc = 27 V using a halfwave power supply.

   a. What is Vpk?

   b. What is Vrms?

3. Emily is using a fullwave power supply that has a DC output of 10.79 V. What is the AC voltage (Vrms)?

SOLUTIONS

1. $V_{dc} = .636\ V_{pk}$

   $V_{pk} = 1.414\ V_{rms}$

   $V_{pk} = 1.414 \times 30$

   $V_{pk} = 42.42$

   $V_{rms} = 30$

   a. $V_{dc} = .636\ V_{pk}$

   $V_{dc} = .636 \times 42.42$

   $V_{dc} = 27\ V$

2. $V_{dc} = 27\ V$

   a. $V_{pk} = \frac{V_{dc}}{.318}$

   $V_{pk} = \frac{27}{.318}$

   $V_{pk} = 84.9$

   b. $V_{rms} = \frac{V_{pk}}{1.414}$

   $V_{rms} = \frac{84.9}{1.414}$

   $V_{rms} = 60\ V$

3. $V_{rms} = \frac{V_{pk}}{1.414}$

   $V_{pk} = \frac{V_{dc}}{.318}$

   $V_{pk} = \frac{10.79}{.318}$

   $V_{pk} = 33.93$

   $V_{dc} = 10.79\ V$

   $V_{rms} = \frac{33.93}{1.414}$

   $V_{rms} = 24\ V$

4. Stan has a choice of a fullwave or halfwave power supply. If he applies 40 Vrms AC to each one,

   a. how much DC will he have on fullwave?

   b. how much DC will he have on halfwave?

5. Minnie has an output on the halfwave power supply of 12.5 volts DC.

   a. What is the AC peak input?

   b. What is the AC voltage (Vrms)?

4. $V_{pk} = 1.414\ v_{rms}$

$V_{pk} = 1.414 \times 40$

$V_{pk} = 56.56$

a. $V_{dc} = .636\ V_{pk}$

$V_{dc} = .636 \times 56.56$

$V_{dc} = 35.97$

b. $V_{dc} = .318\ V_{pk}$

$V_{dc} = .318 \times 56.56$

$V_{dc} = 17.99$

or

$\frac{1}{2}$

5. a. $V_{pk} = \frac{V_{dc}}{.318}$

$V_{pk} = \frac{12.5}{.318}$

$V_{pk} = 39.3$

b. $V_{rms} = \frac{V_{pk}}{1.414}$

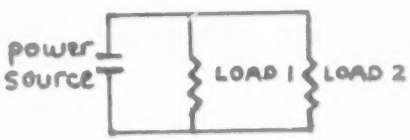
$V_{rms} = \frac{39.3}{1.414}$

$V_{rms} = 27.8\ V$

RESISTANCE

(Parallel)

All devices (loads) used in electronics have opposition or resistance (R). In our homes we use parallel circuits to connect devices to the voltage (E) source. A parallel circuit means that two or more loads are connected across the same power source.



When two or more loads are connected in parallel, the total resistance R_T is equal to the reciprocal of the sum of each resistance (load).

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}}$$

This simply means that in parllel circuit the total (R_T) will always be less than the smallest resistance (R). When only two loads (resistances) are placed in parallel a simpler method can be used to calculate total resistance (R_T), called the product-sum method.

$$R_T = \frac{\text{Product}}{\text{Sum}} \qquad R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

Examples:

Four lights are connected in parallel, the first with 100 ohms of resistance, the second with 75 ohms of resistance, the third with 150 ohms of resistance, and the fourth with 50 ohms of resistance. How much total resistance is there in this circuit?

$$R_T = \frac{1}{\frac{1}{100} + \frac{1}{75} + \frac{1}{150} + \frac{1}{50}} = \frac{1}{\frac{3}{300} + \frac{4}{300} + \frac{2}{300} + \frac{6}{300}}$$

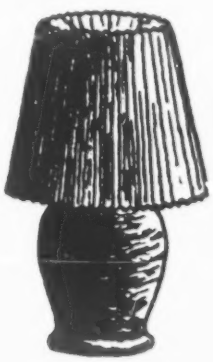
$$R_T = \frac{1}{\frac{15}{300}} = \frac{300}{15}$$

R_T = 20 ohms of resistance

Two lights are connected in parallel, the first with 25 ohms of resistance and the second with 100 ohms of resistance. How much total resistance it there in this circuit?

$$R_T = \frac{R_1 + R_2}{R_1 + R_2} = \frac{25 \times 100}{25 + 100} = \frac{2500}{125}$$

R_T = 20 ohms of resistance



PROBLEMS

Work the following problems concerned with resistance in parallel circuits.

1. At Christmas, we enjoy having a brightly lit Christmas tree, so we can use three strings of lights connected in parallel. The first string has 200 ohms of resistance, the second 50 ohms, and the third 40 ohms. How much total resistance is there in this circuit?

2. When Juls Jones connected two speakers in parallel on his dune buggy, each having 16 ohms of resistance, how much total resistance did he have in the circuit?

3. Jody wanted to light up her deck for a party, so she placed two strings of lights, connected in parallel around the railing. If the first string had 84 ohms of resistance and the second had 43 ohms of resistance, how much total resistance is there in the circuit?

4. Tom connected 6 flashing lights in parallel across the front of his hot dog stand. He knows that 2 had a resistance of 12 ohms, 3 had a resistance of 36 ohms and 1 had a resistance of 53 ohms. What was the total resistance in the circuit?

SOLUTIONS

1. $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

$R_T = \dfrac{1}{\frac{1}{200} + \frac{1}{50} + \frac{1}{40}}$

$\dfrac{1}{\frac{1}{200} + \frac{4}{200} + \frac{5}{200}}$

$\dfrac{1}{\frac{10}{200}}$

$1 \div \frac{10}{200}$

$1 \times \frac{200}{10}$

20 ohms of resistance

2. $R_T = \dfrac{R_1 \times R_2}{R_1 + R_2}$

$R_T = \dfrac{16 \times 16}{16 + 16}$

$= \dfrac{256}{32}$

8 ohms of resistance

3. $R_T = \dfrac{R_1 \times R_2}{R_1 + R_2}$

$R_T = \dfrac{84 \times 43}{84 + 43}$

$R_T = \dfrac{3612}{127}$

$R_T = 28.44$ ohm

4. $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}}$

$R_T = \dfrac{1}{\frac{1}{12} + \frac{1}{12} + \frac{1}{36} + \frac{1}{36} + \frac{1}{36} + \frac{1}{53}}$

$R_T = \dfrac{1}{.083 + .083 + .027 + .027 + .027 + .018}$

$R_T = \dfrac{1}{.265}$

$R_T = 3.77$ ohms

5. Brandon connected four speakers in his car in parallel, 2 in the front and two in the back. The 2 in the front each had 75 ohms of resistance and the two in the back each had 100 ohms of resistance. What is the total resistance in the circuit?

6. David has 3 loads connected in parallel. He knows the total resistance is 10 ohms and that the resistance for one load is 25 ohms and another is 76 ohms. What is the resistance of the third load?

7. Miriam has 4 loads connected in parallel. She knows the total resistance is 5 ohms, and that three of the loads each have the same resistance and they total 66 ohms.

   a. What is the resistance of each of the three loads that have a total resistance of 66 ohms?

   b. What is the resistance of the fourth load?

5. $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$

$R_T = \dfrac{1}{\frac{1}{75} + \frac{1}{75} + \frac{1}{100} + \frac{1}{100}}$

$R_T = \dfrac{1}{.013 + .013 + .01 + .01}$

$R_T = \dfrac{1}{.046}$

$R_T = 21.739$ ohms

6. $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

$10 = \dfrac{1}{\frac{1}{25} + \frac{1}{76} + \frac{1}{x}}$

$\frac{1}{10} = \frac{1}{25} + \frac{1}{76} + \frac{1}{x}$

$.1 = .04 + .013 + \frac{1}{x}$

$.1 = .053 + \frac{1}{x}$

$.1 - .053 = \frac{1}{x}$

$.047 = \frac{1}{x}$

$\frac{1}{.047} = x$

$x = 21.28$ ohms

7. a. $\frac{66}{3} = 22$ ohms

b. $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$

$5 = \dfrac{1}{\frac{1}{22} + \frac{1}{22} + \frac{1}{22} + \frac{1}{x}}$

$5 = \dfrac{1}{.045 + .045 + .045 + \frac{1}{x}}$

$5 = \dfrac{1}{.135 + \frac{1}{x}}$

$\frac{1}{5} = .135 + \frac{1}{x}$ $= .2 = .135 + \frac{1}{x}$ $= .2 - .135 = \frac{1}{x}$

$.065 = \frac{1}{x}$ $= x = \frac{1}{.065}$ $= x = 15.38$ ohms

The following problems require an understanding of the metric system. Tell your teacher if you need assistance.

8. Polly has two lights connected in parallel. The first has a resistance of 42 milliohms, and the second has a resistance of 2 ohms. What is the total resistance of the circuit (in ohms)?

9. James has three speakers connected in parallel. The first has .04 kilohms of resistance, the second has 40 milliohms of resistance, and the third has 6 ohms of resistance. What is the total resistance of the circuit (in ohms)?

10. Jack has 4 loads connected in parallel. The first two each have equal resistance totaling 50 milliohms. The last two each have equal resistance totaling .046 Kilohms.

    a. What is the resistance of each of the first two loads in milliohms?

    b. What is the resistance of each of the last two loads in kilohms?

    c. What is the resistance of loads 1, 2, 3, and 4 in ohms?

    d. What is the total resistance in the circuit (in ohms)?

8. $R_T = \frac{R_1 + R_2}{R_1 + R_2}$ 42 milliohms = .042 ohms

$\frac{42}{1000} = .042$

$R_T = \frac{.042 \times 2}{.042 + 2}$

$R_T = \frac{.084}{2.042}$

$R_T = .04$ ohms

9. .04 kilohms = 40 ohms
.04 x 1000 = 40

40 milliohms = .04 ohms

$\frac{40}{1000} = .04$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

$R_T = \frac{1}{\frac{1}{40} + \frac{1}{.04} + \frac{1}{6}}$

$R_T = \frac{1}{.025 + 25 + .167}$

$R_T = \frac{1}{25.192}$

$R_T = .003969$ ohms

10. a. $\frac{50}{2}$ = 25 milliohms each

b. $\frac{.046}{2}$ = .023 kilohms each

.023 x 1000 = 23

c. 1 & 2: 25 milliohms = .025 ohms

$\frac{25}{1000}$

3 & 4: .023 kilohms = 23 ohms

d. $R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$

$R_T = \frac{1}{\frac{1}{.025} + \frac{1}{.025} + \frac{1}{23} + \frac{1}{23}}$

$R_T = \frac{1}{40 + 40 + .043 + .043}$

$R_T = \frac{1}{80.086}$ = .012 ohms

RESISTANCE
(SERIES)

Every electrical circuit has opposition in it. The amount of current in the wires depends upon the amount of resistance (R) there is in the circuit.

The following formula is used to determine the total resistance in a series circuit:

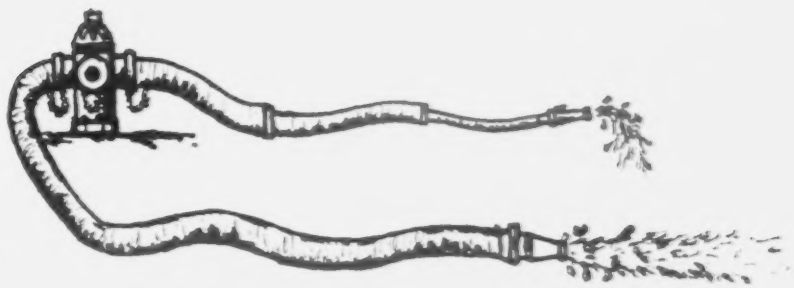
$$R_T = R_1 + R_2 + R_3 \ldots$$

where:

R_T = total resistance (measured in ohms)

R_1 = the first resistance in the series

R_2 = the second resistance in the series, etc.



Example:

What is the total resistance in a series circuit which has three lights? Two lights have a resistance of 4 ohms, and one has a resistance of 1 ohm.

$R_T = R_1 + R_2 + R_3$

$R_T = 4 + 4 + 1$

$R_T = 9$ ohms

PROBLEMS

Work the following resistance problems.

1. Boy George needs five lights connected in series to complete his laser display. If each light has a resistance (R) of 5 ohms, what will be the total resistance in the series circuit?

2. Boy George decided he wanted two of the lights brighter, so he replaced them with lights that had a resistance of one ohm each. What is the total resistance of the circuit now?

3. Boy George wanted lights 1, 3, and 5 to be brighter then lights 2 and 4. He connected the five lights in series with lights 1, 3, and 5, having a resistance of 2 ohms each and lights 2 and 4 having 4 ohms each. What is the total resistance in the series circuit?

SOLUTIONS

1. $R_T = R_1 + R_2 + R_3 + R_4 + R_5$

   $R_T = 5 + 5 + 5 + 5 + 5$

   $R_T = 25$ ohms

2. $R_T = R_1 + R_2 + R_3 + R_4 + R_5$

   $R_T = 1 + 1 + 5 + 5 + 5$

   $R_T = 17$ ohms

3. $R_T = R_1 + R_2 + R_3 + R_4 + R_5$

   $R_T = 2 + 4 + 2 + 4 + 2$

   $R_T = 14$ ohms

The following problems require an understanding of the metric system.

4. Bruce has a series of 3 lights. The first light has a resistance of 4 K ohms, the second has a resistance of 7.5 M ohms and the third has a resistance of 5 ohms. What is the total resistance?

a. in ohms?

b. in milliohms?

c. in microhms?

5. Ruby has a series circuit with a light that has a resistance of 100 milliohms and a bell with a resistance of 5 megaohms. What is the total resistance?

a. in ohms?

b. in milliohms?

4. $R_T = R_1 + R_2 + R_3$

4 Kohms = 4000 ohms

7.5 Mohms = 7,500,000 ohms

A. $R_T = 4000 + 7{,}500{,}000 + 5$

$R_T = 7504005$ ohms

B. 7504005 x .001

7504.005 milliohms

C. 7504005 x .000001

7.504005 microhms

5. $R_T = R_1 + R_2$ 100 milliohms = .1 ohms 5 megaohms = 5,000,000 ohms

A. $R_T = .1 + 5{,}000{,}000$

$R_T = 5{,}000{,}000.1$

B. 5,000,000.1 x .001

5,000.0001

Bonus Problem:

6. Marilyn was working on a special problem for school. She needed to set up a series of seven buzzers. Each buzzer must be proportionately softer than the one before it.

A. If the buzzers are given resistance as shown below, what would the total resistance be?

Buzzer	Resistance
1	.002 kilohms
2	3,000 milliohms
3	4,000,000 microohms
4	.000005 megaohms
5	6,000,000,000,000 picohms
6	7 ohms
7	8 ohms

a. in ohms?

b. in kilohms?

c. in megaohms?

d. in millohms?

e. in microhms?

f. in picohms?

6. A. .002 kilohms = 2 ohms
3,000 millihms = 3 ohms
4,000,000 microhms = 4 ohms
.000005 megahms = 5 ohms
6,000,000,000,000 picohms = 6 ohms

a. $R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$R_T = 2 + 3 + 4 + 5 + 6 + 7 + 8$

$R_T = 35$ ohms

b. 35 ÷ 1,000

.035 Kohms

c. 35 ÷ 1,000,000

.000035 Mohms

d. 35 x 1,000

35000 mohms

e. 35 x 1,000,000

35,000,000 microhms

f. 35 x 1,000,000,000,000

35,000,000,000,000

B. If the total resistance was 7 ohms and you knew buzzer one had a resistance of .25 ohms, buzzer two had a resistance of .50 ohms, buzzer three had a resistance of .75 ohms, and buzzer five had a resistance of 1.25 ohms, buzzer six had a resistance of 1.50 ohms, and buzzer seven had a resistance of 1.75 ohms, what would be the resistance of buzzer four?

C. If the total resistance was 56 ohms and you knew buzzer one had a resistance of 2 ohms, buzzer three had a resistance of 6 ohms, buzzer five had a resistance of 10 ohms and buzzer seven had a resistance of 14 ohms, what would the resistance be for buzzers two, four, and six?

D. If the total resistance is 14 ohms and buzzer one has a resistance of .5 ohms, buzzer four has a resistance of 2 ohms and buzzer seven has a resistance of 3.5 ohms, what would be the resistance of buzzers two, three, five, and six?

E. If the total resistance is 28 and buzzer one has a resistance of 1 ohm, what would be the resistance of the other six buzzers?

B. $R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$7 = .25 + .50 + .75 + R_4 + 1.25 + 1.50 + 1.75$

$7 = 6 + R_4$

$R_4 = 1$ ohm

C. $R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$56 = 2 + R_2 + 6 + R_4 + 10 + R_6 + 14$

Look at the pattern--each buzzer has proportionally more resistance than the one before it.

$R_2 = 4$ ohms
$R_4 = 8$ ohms
$R_6 = 12$ ohms

D. $R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$4 = .5 + R_2 + R_3 + R_4 + R_5 + R_6 + 3.5$

Look at the pattern--each buzzer has proportionally more resistance than the one before it.

$R_2 = 1$ ohms
$R_3 = 1.5$ ohms
$R_4 = 2$ ohms
$R_5 = 2.5$ ohms
$R_6 = 3$ ohms

E. $R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$R_1 = 1$ ohm
$R_2 = 2$ ohms
$R_3 = 3$ ohms
$R_4 = 4$ ohms
$R_5 = 5$ ohms
$R_6 = 6$ ohms
$R_7 = 7$ ohms

$R_T = 28$ ohms

TRANSFORMER RATIOS

In electronics, transformers are used to step-up or step-down voltages. The output (secondary) of a transformer is always directly related to the imput (primary).

Input : Output = primary : secondary

Transformer

The relationship is referred to as ratio. A transformer might have a voltage ratio of 10:1 (10 to 1), which means the primary would have ten times as much voltage as the secondary.

A transformer also has a turns ratio (number of windings). If the secondary has less voltage or turns than the primary, it is a **step-down** transformer and if the secondary has more turns or voltage than the primary, it is a **step-up** transformer.

Example:

A transformer has a 2:1 ratio, with 6 volts on the secondary. What is the voltage on the input?

Input : Output = primary : secondary

2 : 1 = x : 6

$\frac{2}{1} = \frac{x}{6}$ x = 12 volts

123

PROBLEMS

1. Calvin has a transformer with a voltage ratio of 4:1 and has 6 volts on the secondary. How much voltage is on the imput?

2. Sally has a transformer with a turns ratio of 1:5. How much voltage will be on the secondary if Sally puts 120 volts on the primary?

3. What kind of transformers are used (step-up or step-down)

   a. in problem 1?

   b. in problem 2?

Transformer

4. Larry has a transformer with 12 volts on the secondary and 24 volts on the primary.

   a. What is the voltage ratio?

   b. What does this mean?

5. Thomas knows his transformer has ten times more voltage on the primary than on the secondary.

   a. What is the ratio?

   b. If the secondary has 2 volts, how much voltage will be on the primary?

SOLUTIONS

1. $4:1 = x:6$

   $\frac{4}{1} = \frac{x}{6}$

   $x = 24$ volts

2. $1:5 = 120:x$

   $\frac{1}{5} = \frac{120}{x}$

   $x = 600$ volts

3. a. step-down, problem 1

   b. step-up, problem 2

4. a. Input : Output = Primary : Secondary

   Input : output = 24 : 12

   $\frac{\text{Input}}{\text{Output}} = \frac{24}{12}$ REDUCE

   $\frac{\text{Input}}{\text{Output}} = \frac{2}{1}$

   b. the primary has twice as much voltage as the secondary.

5. $\frac{\text{Input}}{\text{Output}} = \frac{\text{primary}}{\text{secondary}}$

   a. 10 : 1

   b. $\frac{10}{1} = \frac{x}{2}$

   $10 \times 2 = x$

   $20 = x$

   20 volts on the primary

The following problems require an understanding of the metric system. Tell your teacher if you need assistance.

6. Melony knows that the transformer in the stage-lighting circuit has a ratio of 230:110.

   a. If there is 10 millivolts on the secondary, how many millivolts are on the primary?

   b. How many volts on the primary?

   c. How many volts on the secondary?

7. A step-down transformer has a ratio of 50,000:250, and has 2.7 Kilovolts on the primary.

   a. How many volts on the primary?

   b. How many volts on the secondary?

8. A step-up transformer has a ratio of 4,000:5,550 and has 600 microvolts on the secondary.

   a. How many microvolts on the primary?

   b. How many volts on the primary?

   c. How many volts on the secondary?

Transformer

6. a. 230 : 110 = x : 10 b. 20.9 millivolts = .0209 volts c. 10 millivolts = .01 volts

$\frac{230}{110} = \frac{x}{10}$ $\frac{20.9}{10^3}$ $\frac{10}{10^3}$

$230 \times 10 = 110x$

$2300 = 110x$

$\frac{2300}{110} = x$

$20.9 = x$

20.9 millivolts on the primary

7. a. 2.7 Kilovolts = 2700 volts

2.7×10^3

b. input : output = primary : secondary

50,000 : 250 = 2700 : x

$\frac{50,000}{250} = \frac{2700}{x}$

$50,000x = 675,000$

$x = \frac{675,000}{50,000}$ x = 13.5 volts

8. a. input : output = primary : secondary

4,000 : 5,550 = x : 600

$\frac{4,000}{5,550} = \frac{x}{600}$

$600(4,000) = 5,550x$

$2,400,000 = 5,550x$

$\frac{2,400,000}{5,550} = x$

$432.4 = x$

432.4 microvolts on primary

b. 432.4 microvolts = .0004 volts on primary

$\frac{432.4}{10^6} = .0004$

c. 600 microvolts = .0006 volts on secondary

$\frac{600}{10^6} = .0006$

VOLTAGE

The devices we use every day in electronics use voltage to operate. Kirchoff proved that devices connected in series share the voltage (E) applied to the circuit. So that the applied E equals the sum of the voltage drops

$$E_T = E_{R_1} + E_{R_2} + E_{R_3} + E_{R4}$$

Where:

E_T = applied voltage

E_R = voltage appearing across a device (voltage drop)

Therefore, we can use one battery to supply several different value voltages.

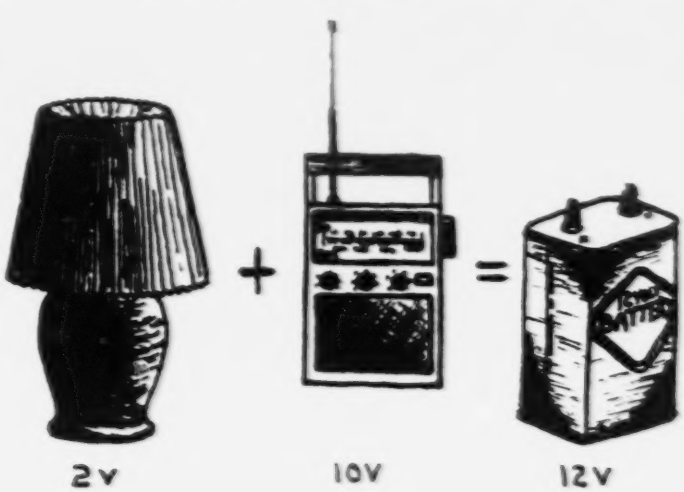
Example:

What is the minimum size battery needed to operate a 2 volt light and a 10 volt radio connected in series?

$E_T = E_{R_1} + E_{R_2}$

$= 2 + 10$

$= 12$ volt battery



PROBLEMS

Work the following problems using Kirchoff's equation.

1. If little Sammy Dew Drop connected in series a light that uses 4 volts, a radio that uses 24 volts, and a horn that uses 2 volts, on his bicycle, what size battery is needed to operate all of these devices?

2. When Mr. Jackson remodeled his workshop he decided to use a radio that required 6 volts, a battery powered light that needs 4 volts and a warning light that operates on 2 volts. What size battery is necessary to operate all of these devices at the same time?

3. Jason has a 4 volt radio and a 7 volt radio, a 3 volt light and a 6 volt light, a 2 volt buzzer and a 5 volt buzzer. He wants to connect one of each in series and use his new 12 volt battery to power them.

   a. Name three combinations of the three devices that will use exactly 12 volts.

   b. There is one other combination that Jason can use with his 12 volt battery. What is it?

SOLUTIONS

1. $E_T = E_{R_1} + E_{R_2} + E_{R_3}$

   $E_T = 4 + 24 + 2$

   $E_T = 30$ Volts

   Sammy would need a 30 volt battery.

2. $E_T = E_{R_1} + E_{R_2} + E_{R_3}$

   $E_T = 6 + 4 + 2$

   $E_T = 12$ Volts

   Mr. Jackson would need a 12 volt battery.

3. a.

7 volt radio	4 volt radio	4 volt radio
3 volt light	6 volt light	3 volt light
2 volt buzzer	2 volt buzzer	5 volt buzzer
12 volts	12 volts	12 volts

   b.

4 volt radio
3 volt light
2 volt buzzer
9 volts

The following problems require an understanding of the metric system. Tell your teacher if you need assistance.

4. What size battery (in volts) is needed to power the following devices connected in series?

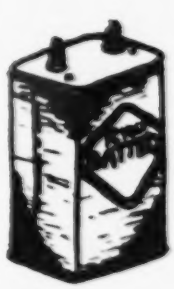
   a. 2000 millivolt bell
      4,000,000,000,000 picovolt light
      6 volt tape player

   b. .000002 megavolt record player
      3,000 millivolt microphone
      3,000,000 microvolt string of lights

5. Erin has a .00001 megavolt radio, a 7,000 millivolt radio and a 5 volt light. Erin wants to connect one of the radios and the light in series and use a 12 volt battery to operate them.

   a. How many volts does the .00001 megavolt radio use?

   b. How many volts does the 7,000 millivolt radio use?



   c. Which radio should Erin use with the light?

4. a. 2,000 millivolts = 2 volt bell
4,000,000,000,000 picovolts = 4 volt light
6 volt tape player
12 volt battery is needed

b. .000006 megavolts = 6 volt record player
3,000 millivolts = 3 volt microphone
300,000 microvolts = 3 volt string of lights
12 volt battery is needed

5. a. 10 Volts

b. 7 Volts

c. the 7,000 millivolt radio

WAVELENGTH

Radio waves travel at the speed of sound, 300,000,000 meters per second. The distance a radio wave travels during one cycle is its wavelength (λ).

$$\lambda = \frac{300,000,000}{f}$$

where

λ = wavelength

f = Frequency (Hz) number of cycles per second

300,000,000 (3×10^8) is the distance traveled per second in meters.

Wavelengths are important because the length of antennas are determined by frequencies being received or transmitted. Antennas can be made in lengths varying from full wave when the antenna length equals the wavelength or shorter by even multiples of the wavelength.

Example:

If the frequency is 75 MHz, what is the wavelength?

$$\lambda = \frac{300,000,000}{f}$$

75 MHz = 75,000,000 Hz

$$\lambda = \frac{300,000,000}{75,000,000}$$

$$\lambda = 4$$

A full wave antenna would be 4 meters long.
A half wave antenna would be 2 meters long.
A quarter wave antenna would be 1 meter long.

Problems

Work the following problems to better understand how frequency, wavelength, and radio antennas are related.

1. If a half wave antenna is 5 meters long, how long would a full wave antenna be?

2. If a quarter wave antenna is 2 meters long, how long would a full wave antenna be?

3. Freddy wants to build an antenna for his new ham radio receiver. The frequency he wants to receive from Germany has a frequency of 10 MHz. How long (wavelength) would a full wave antenna be?

SOLUTIONS

1. $5 \times 2 = 10$ meters

2. $2 \times 4 = 8$ meter

3. $10\ \text{MHz} = 10 \times 1{,}000{,}000 = 10 \times 10^6$

$$\frac{3 \times 10^8}{f} \qquad \text{or} \qquad \frac{3 \times 10^8}{f} =$$

$$\frac{300{,}000{,}000}{10{,}000{,}000} = \qquad \frac{3 \times 10^8}{10 \times 10^6} =$$

$$.3 \times 10^{8-6} =$$

$$30 \text{ meters} \qquad .3 \times 10^2 =$$

$$30 \text{ meters}$$

4. Freddy's friend Jason also has a new ham radio. He wants to build a 1/2 wave antenna to receive a frequency of 10 MHz from Germany.

   a. How long should the 1/2 wavelength antenna be?

   b. How long would a quarter wave antenna be?

5. Jacob has a full wave antenna that is 15 meters long. What frequency will the antenna receive?

   a. in Hz?

   b. in MHz?

6. Joanna has a quarter wave antenna that is 10 meters long. What frequency will it receive?

   a. in Hz?

   b. in MHz?

4. Work same as for problem 3.

a. $\frac{1}{2}$ of 30 meters = 15 meters

b. $\frac{1}{4}$ of 30 meters = 7.5 meters

5. a. $\lambda = \frac{300,000,000}{f}$

$15 = \frac{300,000,000}{f}$

$15\,F = 300,000,000$

$F = \frac{300,000,000}{15}$

$F = 20,000,000$ Hz

b. $\frac{20,000,000}{10^6}$

2 MHz

6. a. $\lambda = \frac{300,000,000}{f}$

10 x 4 = 36 meters

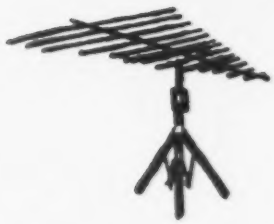
$40 = \frac{300,000,000}{f}$

$40\,F = 300,000,000$

$F = \frac{300,000,000}{40}$

F = 7,500,000 Hz

b. 7.5 MHz



7. If a half wave antenna is 6 meters long, how long would a quarter wave antenna be?

8. If a quarter wave antenna is 2.5 meters long, how long would a full wave antenna be?

9. Sampson had a half wave antenna 6.14 meters long. Gerald had a quarter wave antenna 3.25 meters long. If they each changed to full wave antennas, who would have the longest antenna? How long would each antenna be?

10. To receive a frequency of 12 MHz using a quarter wave antenna, how long should the antenna be?

7. $\frac{6}{2}$ = 3 meters

8. 2.5 x 4 = 10 meters

9. Gerald

   Sampson --6.14 x 2 = 12.28 meters

   Gerald--3.25 x 4 = 13.00 meters

10. 12 MHz = 12,000,000 Hz

    $= \frac{300,000,000}{12,000,000}$

    = 25

    $\frac{25}{4}$ = 6.25 meters